



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

### Usage guidelines

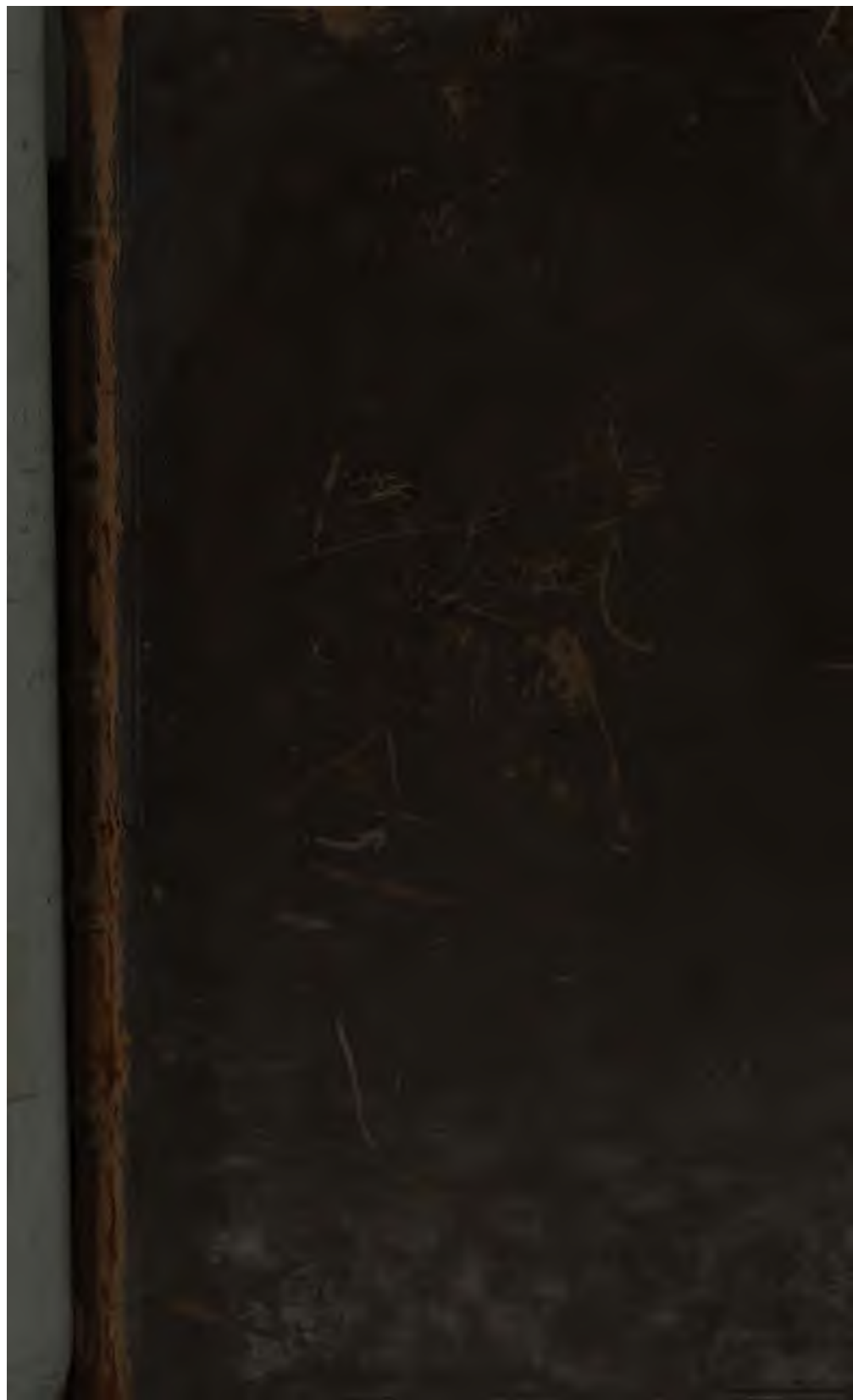
Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

### About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>



8 c. 14

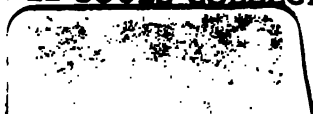


600036571S



1933 c. 211

GIVEN TO THE LIBRARY  
BY ALL SOULS COLLEGE

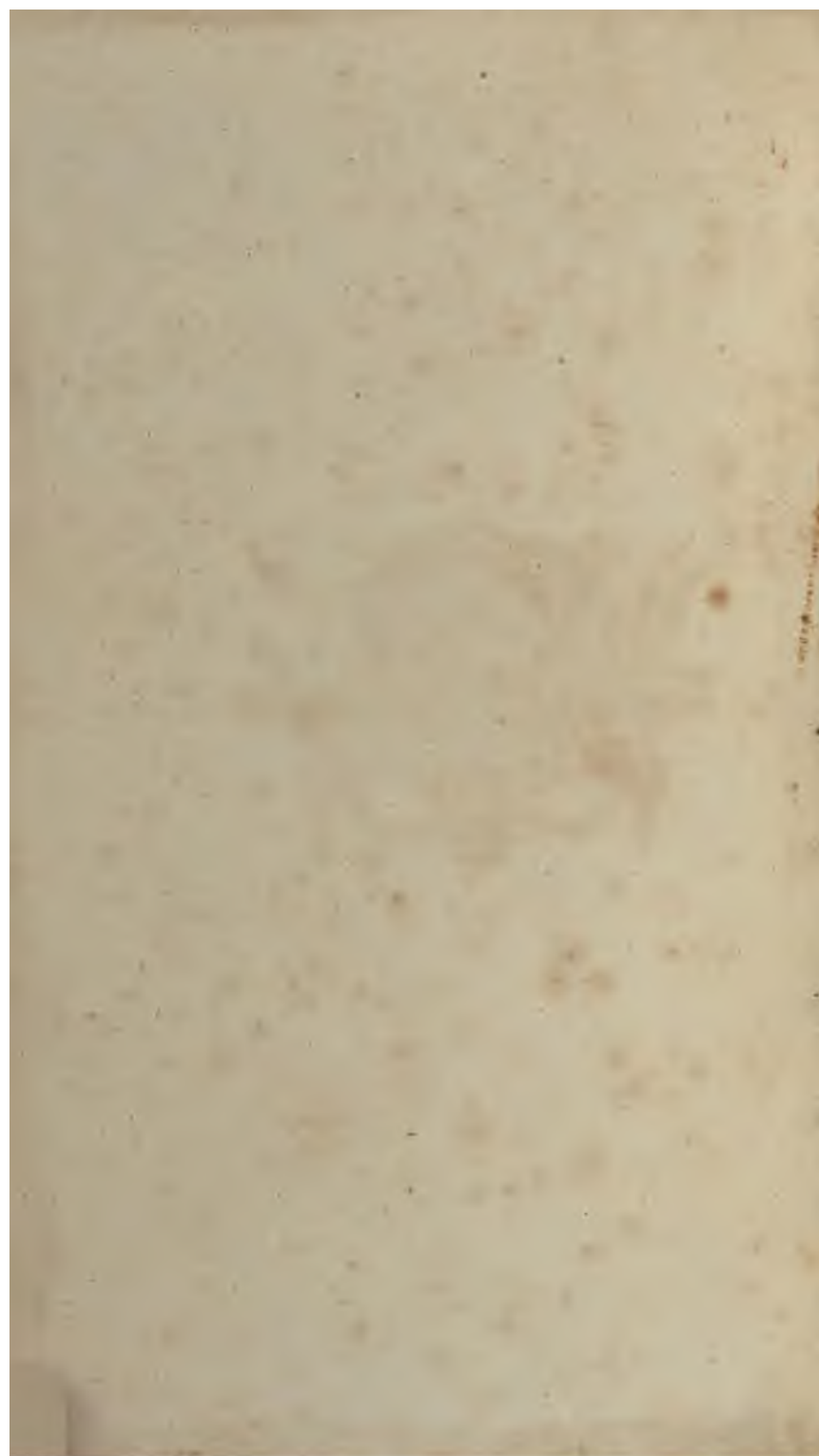








A  
GENERAL SYSTEM  
OF  
CHEMICAL KNOWLEDGE,  
&c. &c.



**A**  
**GENERAL SYSTEM**  
**OF**  
**CHEMICAL KNOWLEDGE,**  
**&c. &c.**



A  
**GENERAL SYSTEM**  
OF  
**CHEMICAL KNOWLEDGE;**  
AND ITS  
**APPLICATION**  
TO THE  
**PHENOMENA OF NATURE AND ART.**

---

BY A. F. FOURCROY,

Of the National Institute of France, Counsellor of State, Professor  
of Chemistry at various Public Establishments, Member  
of many Academies, &c.

---

IN ELEVEN VOLUMES.

TOGETHER WITH A SET OF SYNOPTIC TABLES, IN LARGE FOLIO.

---

TRANSLATED FROM THE ORIGINAL FRENCH,

BY WILLIAM NICHOLSON.

---

VOL. V.

---

LONDON:

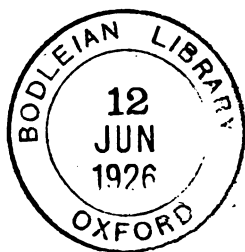
PRINTED FOR CADELL AND DAVIES, STRAND; LONGMAN  
AND REES, G. AND J. ROBINSON, AND J. WALKER,  
PATERNOSTER-ROW; VERNOR AND HOOD, POULTRY;  
CLARKE AND SONS, PORTUGAL-STREET; CUTHELL  
AND MARTIN, AND OGILVY AND SON, HOLBORN;  
AND S. BAGSTER, STRAND.

---

1804.

W. Flint, Printer, Old Bailey.





# TABLE OF CONTENTS

## OF THE FIFTH VOLUME.

### SECTION SIXTH.

#### Concerning the Metals.

	Page.
ART. I. <i>Of the general and comparative Properties of the Metals, and their Classification.....</i>	1
Sec. I. <i>Their Importance and History</i>	ib.
Sec. II. <i>On their Number and Classification.....</i>	10
Sec. III. <i>On their Physical Properties.....</i>	15
Sec. IV. <i>Concerning their Natural History.....</i>	30
Sec. V. <i>Concerning the Assaying of Ores or Docimasy.....</i>	37
Sec. VI. <i>Concerning Metallic Works in a large Way, or Metallurgy...</i>	43
Sec. VII. <i>Concerning the Oxidability or Combustibility of Metals by the Air.....</i>	50
Sec. VIII. <i>Concerning the Combinations of Metals with Combustible Bodies.....</i>	58
VOL. V.	b
	Sec



	Page
Sec. IX. <i>Concerning the mutual Action of the Metals, of Water, and of the Oxides</i> .....	62
Sec. X. <i>Concerning the general Action of the Acids upon the Metals, and the Metals upon the Acids</i> ....	66
Sec. XI. <i>Concerning the mutual Action of the Metals and the Salifiable Bases</i> .....	76
Sec. XII. <i>Concerning the mutual Action of the Metals and the Salts</i>	80
ART. II. <i>Concerning Arsenic and its Acid</i> .....	83
Sec. I. <i>Concerning Metallic Arsenic</i>	
A <i>History</i> .....	ib.
B <i>Physical Properties</i> .....	85
C <i>Natural History</i> .....	86
D <i>Docimastic and Metallurgic Operations</i> .....	89
E <i>Oxidability by the Air</i> .....	92
F <i>Union with Combustible Matters</i>	ib.
G <i>Action upon Water, and the Oxides</i> .....	94
H <i>Action with Acids</i> .....	96
I <i>Action on the Bases and Salts</i>	99
K <i>Uses</i> .....	100
Sec. II. <i>Of the Arsenious and Arsenical Acids</i>	
Species I. <i>The Arsenious Acid</i> ....	102
	Species

# TABLE OF CONTENTS.

vii

	Page.
Species II. <i>The Arsenical Acid</i> .....	108
ART. III. <i>Concerning Tungsten and its Acid</i> .....	117
Sec. I. <i>Concerning the Metal Tungsten</i>	
A <i>History</i> .....	ib.
B <i>Physical Properties</i> .....	118
C <i>Natural History</i> .....	ib.
D <i>Affay and Metallurgy of its Ores</i> .....	119
E <i>Oxidability by the Air</i> .....	120
F <i>Union with Combustibles</i> .....	ib.
G <i>Action upon Water, and the Oxides</i> .....	121
H <i>Action with Acids</i> .....	ib.
I <i>Action on the Bases and Salts</i>	122
K <i>Uses</i> .....	123
Sec. II. <i>Concerning the Tungstic Acid</i>	124
ART. IV. <i>Concerning Molybdena and its Acid</i> .....	129
Sec. I. <i>Concerning the Metal Molybdena</i>	
A <i>History</i> .....	ib.
B <i>Physical Properties</i> .....	131
C <i>Natural History</i> .....	132
D <i>Affay and Metallurgy</i> .....	133
E <i>Oxidability by Air</i> .....	134
F <i>Union with Combustible Bodies</i>	135
G <i>Action of Water, and the Oxides</i>	ib.
H <i>Action of Acids</i> .....	ib.
b 2	I <i>Action</i>

	Page.
I <i>Action on the Bases and Salts</i>	136
K <i>Uses</i> .....	ib.
Sec. II. <i>Concerning the Molybdic Acid</i> .....	137
* ART. V. <i>Concerning Chrome and its Acid</i> .....	145
Sec. I. <i>Of the Metal Chrome</i>	
A <i>History</i> .....	ib.
B <i>Physical Properties</i> .....	147
C <i>Natural History</i> .....	148
D <i>Docimasy and Metallurgy</i> ....	ib.
E <i>Oxidability by Air</i> .....	ib.
F <i>Union with Combustibles</i> .....	149
G <i>Action upon Water and the Oxides</i>	ib.
H <i>Action upon Acids</i> .....	ib.
I <i>Action upon the Bases and Salts</i>	150
K <i>Uses</i> .....	ib.
Sec. II. <i>Concerning the Chromic Acid</i>	151
ART. VI. <i>Concerning Titanium</i>	
A <i>History</i> .....	154
B <i>Physical Properties</i> .....	156
C <i>Natural History</i> .....	ib.
D <i>Assay and Metallurgy</i> .....	158
E <i>Treatment by Fire and Air</i> ....	159
F <i>Treatment with Combustible Bodies</i> .....	160
G <i>Treatment with Water and Oxides</i> .....	161
H <i>Treatment with Acids</i> .....	163
I <i>Treatment with Bases and Salts</i>	169
K <i>Uses</i>	

# TABLE OF CONTENTS.

ix.

	Page.
K <i>Uses</i> .....	171
ART. VII. <i>Concerning Uranite</i>	
A <i>History</i> .....	172
B <i>Physical Properties</i> .....	175
C <i>Natural History</i> .....	176
D <i>Affay and Metallurgy</i> .....	178
E <i>Oxidability by Air</i> .....	179
F <i>Treatment with Combustibles</i>	ib.
G <i>Action upon Water and the</i> <i>Oxides</i> .....	180
H <i>Treatment with Acids</i> .....	ib.
I <i>Treatment with the Bases and</i> <i>Salts</i> .....	182
K <i>Uses</i> .....	183
ART. VIII. <i>Concerning Cobalt</i>	
A <i>History</i> .....	184
B <i>Physical Properties</i> .....	185
C <i>Natural History</i> .....	187
D <i>Affay and Metallurgy</i> .....	191
E <i>Oxidability by Air</i> .....	194
F <i>Union with Combustibles</i> ....	195
G <i>Action upon Water and the</i> <i>Oxides</i> .....	197
H <i>Action upon Acids</i> .....	ib.
I <i>Action upon the Bases and Salts</i>	202
K <i>Uses</i> .....	203
ART. IX. <i>Concerning Nickel</i>	
A <i>History</i> .....	205
B <i>Physical Properties</i> .....	206
C <i>Natural History</i> .....	207
D <i>Affays</i>	

	<b>Page.</b>
<b>D</b> <i>Assays and Metallurgy</i> .....	210
<b>E</b> <i>Oxidability by the Air</i> .....	222
<b>F</b> <i>Union with Combustibles</i> .....	223
<b>G</b> <i>Action upon Water and the Oxides</i> .....	224
<b>H</b> <i>Action upon Acids</i> .....	ib.
<b>I</b> <i>Action upon Bases and Salts</i> .....	226
<b>K</b> <i>Uses</i> .....	228
<b>ART. X. Of Manganese</b>	
<b>A</b> <i>History</i> .....	229
<b>B</b> <i>Physical Properties</i> .....	232
<b>C</b> <i>Natural History</i> .....	233
<b>D</b> <i>Assays and Metallurgy</i> .....	237
<b>E</b> <i>Treatment by Fire and Air</i> ....	239
<b>F</b> <i>Treatment with Combustible Bodies</i> .....	246
<b>G</b> <i>Action upon Water and the Oxides</i> .....	247
<b>H</b> <i>Treatment by the Acids</i> .....	249
<b>I</b> <i>Treatment by the Bases and Salts</i> .....	259
<b>K</b> <i>Uses</i> .....	265
<b>ART. XI. Bismuth</b>	
<b>A</b> <i>History</i> .....	266
<b>B</b> <i>Physical Properties</i> .....	267
<b>C</b> <i>Natural History</i> .....	269
<b>D</b> <i>Assay and Metallurgy</i> .....	272
<b>E</b> <i>Oxidability by the Air</i> .....	274
<b>F</b> <i>Union with Combustible Substances</i> .....	276
<b>G</b> <i>Action</i>	

# TABLE OF CONTENTS.

xi

	Page.
G <i>Action of Water and the Oxides</i>	279
H <i>Action of the Acids</i> .....	280
I <i>Action upon, the Salifiable Bases</i> <i>and Salts</i> .....	286
K <i>Uses</i> .....	288
ART. XII. <i>Concerning Antimony</i>	
A <i>History</i> .....	289
B <i>Physical Properties</i> .....	293
C <i>Natural History</i> .....	296
D <i>Assays and Metallurgy</i> .....	299
E <i>Oxidability by the Air</i> .....	304
F <i>Union with Combustible Sub-</i> <i>stances</i> .....	310
G <i>Action upon Water and the</i> <i>Oxides</i> .....	316
H <i>Action of the Acids</i> .....	319
I <i>Action of the Salifiable Bases and</i> <i>Salts</i> .....	330
K <i>Uses</i> .....	338
ART. XIII. <i>Of Tellurium</i>	
A <i>History</i> .....	360
B <i>Physical Properties</i> .....	361
C <i>Natural History</i> .....	362
D <i>Docimasy</i> .....	363
E <i>Oxidability by the Air</i> .....	366
F <i>Combination with Combustible</i> <i>Bodies</i> .....	ib.
G <i>Action upon Water and the</i> <i>Oxides</i> .....	367
H <i>Action upon the Acids</i> .....	ib.

	Page.
I <i>Action upon the Bases and Salts</i>	370
K <i>Uses</i> .....	371
ART. XIV. <i>Of Mercury</i>	
A <i>History</i> .....	372
B <i>Physical Properties</i> .....	378
C <i>Natural History</i> .....	392
D <i>Affays and Metallurgy</i> .....	397
E <i>Oxidability by the Air</i> .....	406
F <i>Union with Combustible Bodies</i>	414
G <i>Action upon Water and the Oxides</i> .....	431
H <i>Action upon the Acids</i> .....	434
I <i>Action upon Bases and Salts</i> ....	498
K <i>Uses</i> .....	502
ART. XV. <i>Of Zinc</i>	
A <i>History</i> .....	505
B <i>Physical Properties</i> .....	508
C <i>Natural History</i> .....	512
D <i>Affay and Metallurgy</i> .....	517
E <i>Oxidability by the Air</i> .....	522
F <i>Union with Combustible Sub- stances</i> .....	526
G <i>Action upon Water and the Oxides</i> .....	530
H <i>Action upon Acids</i> .....	532
I <i>Action upon the Bases and Salts</i>	545
K <i>Uses</i> .....	549

A  
S Y S T E M  
OF  
CHEMICAL KNOWLEDGE.

---

SECTION SIXTH.

*Concerning the Metals.*

ARTICLE I.

*Of the General and Comparative Properties of the  
Metals, and their Classification.*

SECTION I.

*Their Importance and History.*

1. **I**N the second section of this work we considered the metals only as appertaining to the class of combustible bodies; and the general properties which I have described, were relative merely to their comparison with the small number of substances I had before treated. In the present section my object will be of much greater extent; namely, to describe at length these brilliant bodies so useful in society; which so



## 2 GENERAL PROPERTIES OF METALS.

highly influence public and individual prosperity, not only by their real properties, but by the ideal value attached to them by men ; which have on the one hand rendered such eminent services to humanity, and on the other produced so many evils ; which at the same time mark the industry of nations, and add to the improvement of human reason, while they so often become the instruments, and almost the cause, of the depravation, the misery, and all the evils which afflict mankind. There are no productions of nature which excite a higher degree of interest in their study, or which have given rise to so many discoveries : there are not, consequently, any substances which deserve to be treated more at length, or with greater care.

2. The multiplied uses to which the metals are applicable, do not constitute the only reason why these bodies should be described with much accuracy, and studied with the greatest precision. The vast influence which they have had on the progress of chemistry, the discoveries which relate to them, particularly in modern times, and the perfection which they have added to human reason, render them of the most impressive consequence to those who cultivate natural philosophy. On the properties of these bodies depend the mariners' compass, the arts of printing, of navigation and astronomy, and every other science which are most truly honourable to the genius of man. There is, in truth, no

art

art which can be carried on without the metals. They are the first movers and primary instruments of almost every workshop. There is scarcely a single circumstance of life in which we do not derive continual services, or in which we are not subjected to dangers from their energy. The metals are friends which serve us, and which it is desirable we should always have near us; or they are enemies pressed into our employ, which it is consequently of importance that we should know how to subdue, and sometimes to coerce. The science of medicine, which in all the regions of nature has fought for defence against the evils which afflict humanity, and from which it would be perhaps dangerous to obliterate the illusions of hope with which it surrounds the bed of sickness, even when to cure is beyond its power; this science has discovered in metallic substances a number of remedies which can never be considered with indifference, and of which the most sublime chemistry is often called upon, either to determine the nature, to direct the activity, or to regulate the power according to the wish of the enlightened physician.

3. Though the accidental effect of certain natural events, or spontaneous fires, may have at first exhibited the metals to the observation of man, it is easy to conceive that rapid progress must have been made in the treatment of these substances. In the early infancy of chemistry, almost contemporary in this point of view

#### 4 GENERAL PROPERTIES OF METALS.

with the first ages of civilization; when we direct our attention to the heroic, fabulous, and most early ages; in these times we find that smiths and founders were actively employed. The plough-share dates as early in point of time as the coarse casts of the gods in metal. But notwithstanding this high antiquity of the metallic arts, in which the historians of chemical science have been desirous of fixing its origin, the ancients were in truth possessed of but a small portion of real knowledge respecting the properties of metals.

Iron, copper, gold, and silver, have manifestly been the first known and employed. Tin and lead must have followed speedily afterwards, if they were not discovered, even at the same time or before. The art of smelting, of casting, of forging, and even of alloying them, must soon have succeeded; but the true chemical properties were long concealed in the bosom of nature, and discoveries of this kind were undoubtedly made with extreme slowness. The Greeks and the Romans were acquainted with only seven metals. It appears that some of those which were since called semi-metals were known to them only under peculiar names, and with notions foreign to that of their proper metallic nature. This is so much the more natural, as the property of ductility, which is the most useful to men, and of which they avail themselves the most early, must always have connected itself with them as part of the

2

the

the notion of a metal. Even at present, notwithstanding the vast mass of information discovered respecting such metallic bodies as are not ductile, and the numerous uses to which most of them are appropriated, the greatest part of men do not even now consider any substances as metals but those which are capable of being forged, flattened, drawn out, &c.

4. The follies and imaginary hopes of the alchemists and adepts, a disease of the human mind which it is so difficult to extirpate in the social state, and of which some vestiges still remain, though happily scattered, and little likely to propagate themselves, have nevertheless proved the source from which all our chemical knowledge of the metals originated. The indefatigable patience of these men; the numberless experiments they made; the admirable law which they imposed on themselves to describe with the greatest care these experiments which did not afford their chemical result, at the same time that they carefully concealed those which they affirmed to have succeeded, have gradually raised that edifice which Science began to possess from the middle of the seventeenth century, and which has speedily been enlarged by the labours of the chemists, whose method, intelligence, and reason, have enabled them to dispose with art all the shapeless materials, amassed with so much labour by the industrious searchers after the philosopher's stone, and the universal medicine.

CHAPTER

5. After

## 6 GENERAL PROPERTIES OF METALS.

5. After the absurd researches, though abounding with singular facts of Geber, Morien, Arnaud de Villeneuve, Raymond Lullius, Bernard Trevisan, Agrippa, Ifaacus, Hollandus, Bazil Valentine, Philalethes, Morhof, Sendigove, D'Espagnet, and so many other celebrated enthusiasts, we behold, on the other hand, Libavius, Dörneus, Hahnemam, Gerhard, Cassius, Wedel, Orschall, and many other men of this order, busy themselves in extracting the pearls from this dunghill, separating the useful facts from the ridiculous assertions, the valuable experiments from the mystical operations, and by these means making an advantageous selection of the art; and though they were not intirely without credulity, as to the great work and the panacea, yet they reduced to order, and with a certain degree of skill, arranged the results of the observations of the alchemists, so far as to form the commencement of a theory respecting the properties of metallic substances.

6. Chemical metallurgy has been more particularly benefited by the works of docimacy and metallurgy, treated either as arts or as a science, which have been published since the middle of the sixteenth century to the end of the eighteenth, and particularly by those which have been successively printed by J. Q. Agricola, in 1546, Lazarus Ercker, 1574, Modestus Fachsius, 1622, Alonzo Barba, 1640, Aldrovandus, 1648, Borrichius, 1674, Fr. Henckel, 1725, Swedenborg, 1734, Schulutter, 1738, Cramer 1739, Gellert,

Gellert, 1765, Lehman, 1761, Wallerius, 1770, Dellius, Gobet, Jars, Bergmann, Dietrich, Born, Ferber, and Pfingsten, in modern times. In all these works the treatment of ores and metals in the large or small way, in the metallurgic, or docimastic methods, has been enlightened by the most perspicuous theory, and described as a series of chemical experiments, and consequently connected with the general progress of the science.

7. During the uninterrupted advance of the metallic arts for near two hundred years, towards a scientific doctrine, upon the progress and advancement of which they have had great influence, another step of equal utility was made in the preparation, the nature, and the administration of medicines composed of the metals, and the art of making chemical experiments, the method of comparing them, and the drawing general inductions, or theoretic results. While we contemplate the absurd and vain pretensions of Paracelsus, Digby, and others, we must not overlook the useful labours of J. Silvius, Leo, Fachsius, Val Cordus, Quercetan, Mynsicht, Crollius, Zwelfer, Schroder, Fred. and Gasp. Hoffman, Angelus Sala, Glauber, Charas, Nicholas Lemery, Barchusen, Juncken, Pelletier, Shaw, Hermann, Wallerius, Perner, Poullietier de la Salle, Lewis, and Spielman. In the numerous writings of these pharmacological chemists, published between the years 1755 and 1775, we find a methodical disposition,

## 8 GENERAL PROPERTIES OF METALS.

tion, learned discussion, and neat description of the chemical alterations which the metals are capable of undergoing by all the agents to which they are subjected, and thus modified, in their properties and nature.

8. It is in these valuable collections of facts, of experiments and of well-described phenomena, that the systematical chemical writers who are obliged to embrace the whole of the mutual re-actions of all the bodies in nature, upon each other, have found the elements of accurate knowledge, with which they have afterwards enriched their works. Without the laborious efforts of their predecessors; their treatises, far from being so complete as they were capable of making them, would, in all their sections, have presented immense vacancies in the exhibition of metallic matters, of which the properties constantly form the greatest, and at the same time, the most important part of their works.

9. To these multiplied registers of experiment and research concerning metallic substances, we must also join, in order to obtain a sufficient knowledge of the history of that part of chemistry which concerns them, a knowledge of the numerous discoveries of new metals made, particularly since the commencement of the 18th century. During this period, discovery was made of arsenic, cobalt, nickel, and platina itself, before scarcely known. During the last twenty years, manganese, molybdena, tungsten, and recently uranium, titanium, and chrome,  
have

have been added. All these metals which are very brittle, and more or less difficult to fuse, remained long concealed and unknown to man, because ductility had been considered as the inseparable character of metallic substances. Since the series of these substances has been discovered, which do not possess ductility, every fact seems to announce, that their number may hereafter be carried far beyond the present extent of our knowledge.

10. The course of successive discovery and information thus gradually acquired, and which, I have here traced out, did not yet present any certainty of doctrine in the midst of numerous facts which composed its totality. We may even add, that a great number of doctrines presented errors of no small magnitude, and that most of these facts were inaccurate sketches before Lavoisier published his happy discoveries respecting the calcination of metals, their solution in the acids, the decomposition of acids, and particularly that of water, which many of these bodies effect. All the efforts of Bergmann to determine the proportion of an imaginary principle admitted since the commencement of the century, in metals, were little more than a confirmation of an ancient error; lending to that error, a fictitious support, until Lavoisier, overthrowing by his ingenious experiments this false hypothesis, created and caused to arise out of his new results respecting the nature of air, water, and the acids, a doctrine, which dispelled



pelled all the difficulties so abundant in the history of the metals, showed the cause of their so frequent augmentation of weight, their reduction, their solution, and at length presented them to chemists as indecomposable passive instruments, indestructible with regard to their intimate composition, simply changing their form in all the alterations to which they are subjected; and acting, as the means of decomposition on a number of compound bodies, the nature of which they are adapted to show. Since this remarkable epocha, which must be considered as of importance to the progress of the human mind, the science has advanced with a rapid course in the knowledge of the metals, and the determination of the phenomena they produce; discoveries have suddenly followed; every thing which was obscure, has become enlightened; and this admirable department of chemistry, enriched with a number of new facts, has, at the same time, enlightened the workshops of assays and metallurgy, together with mineralogy, and all the arts which employ the metals.

## SECTION II.

### *On the Number and Classification of the Metals.*

11. WHEN no other bodies were considered as metals but those which possess ductility, and

when their number was confined to six or seven, it was not necessary to seek after many properties, nor to establish any method for distinguishing and ascertaining each of these bodies. The notion of forming a classification, must have scarcely occupied the attention of chemists.

12. At the period when the existence of a number of brittle metallic matters was ascertained, and it was admitted, that all their properties approach those of the ductile metals, these began to be distinguished by the terms, semi-metals, as if ductility were the most essential character of these bodies in nature, as it is in the uses of art. Man, therefore, referring every thing to himself, and his events, gave to these beings a determinate rank and place from their utility to himself. Another idea, less reasonable, no doubt, tended to confirm this expression of the semi-metals. The alchemists imagined that all the metals were only efforts of nature towards the production of gold, considered as the most perfect of metals, and that, by a subterraneous operation of nature, inimitable by art, they were capable of arriving at a state of maturity and perfection so as to become gold; and that all the metals were only successive states from a less to a greater degree of perfection, unto the last state, namely, aurification. Now, as ductility is one of the most prominent characters of gold, and the metals properly so called, approach more or less to it by this character; those metals which did not possess

#### 14 CLASSIFICATION OF METALS.

applied to them. This class contains eight species, namely,

Titanium,  
Uranium,  
Cobalt,  
Nickel,  
Manganese,  
Bismuth,  
Antimony.  
Tellurium,

It may be remarked, that of all the five classes this is the most numerous.

18. To the third class appertain metals simply oxidable like those of the second class, but which differ from it by a commencement of ductility. Two metals only compose this third division, mercury and zinc. The first congealed at a temperature of 32 degrees below 0, of the thermometer of Reaumur, may be flattened by percussion. It is the least numerous in species of the five classes. The metals of these three first classes were formerly called semi-metals.

19. In the fourth class, I place the very ductile metals differing in this respect from those of the preceding classes, which were only slightly, but easily oxidable, and distinguished by that character from the following class. In this class are four metallic substances,

Tin,  
Lead,  
Iron,  
Copper,

These

These four metals formerly composed the series of imperfect metals.

20. Lastly, the fifth class comprehends the very ductile metals so difficultly oxidable or alterable, that a few years ago, they were designated by the expression of perfect metals, as admitting the most perfect assemblage of all the metallic properties. The three species which formed this class are,

Silver,

Gold,

Platina.

21. From this division and arrangement of the twenty-one known metals, there already results a notion of considerable accuracy respecting certain properties, and particularly those by which these bodies are rendered most useful to society. According to this method we might pursue the various comparisons to be pointed out in the following paragraphs relative to the generic properties of metals, before we pass to the individual history of each.

### SECTION III.

#### *On the Physical properties of the Metals.*

22. IN order to understand the characters and phenomena presented by the metals, it is necessary in the first place to form a proper notion of their physical properties, without, however,

## 16 CLASSIFICATION OF METALS.

ever, entering into an extensive detail which belongs to other branches of human knowledge. Among a number of properties perceptible to our senses which may be measured and estimated, and do not change the nature of the metals, I reckon, 1. Their brilliancy, 2. Colour, 3. Density or weight, 4. Hardness, 5. Elasticity, 6. Ductility, 7. Tenacity, 8. Conductibility of caloric, 9. Dilatability, 10. Fusibility, 11. Volatility, 12. Crystallizability, 13. Electricity, 14. Odour. We must resume each of these properties with some developments.

23. Brilliancy, is a character so evident in metals, that it has been denominated the metallic brilliancy. It arises from a complete reflexion of the luminous rays by metallic surfaces. They form mirrors which reflect the perfect images of objects. If any other minerals or fossil substance sometimes present an appearance of brilliancy, as we see in mica, of which the first avaricious conqueror of Peru was the dupe, when he took them for silver and gold, this illusion is destroyed, when the false brilliant is scratched with a point, whereas the metal by the same treatment is no less brilliant in the excavated line, than on the surface. With regard to the gradation of this property, the metals may be placed in the following order,

Platina,  
Iron and steel,  
Silver,

Mercury,

Mercury,  
 Gold,  
 Copper,  
 Tin,  
 Zinc,  
 Antimony,  
 Bismuth,  
 Lead,  
 Arsenic,

Cobalt, and the other brittle metals.

24. Colour, is a constant property inherent to the intimate nature of metals, whereas it is accidental, and not ever specific in other fossils, and as the metals are the most opaque, and the most dense bodies in nature, their colour is very intense, or rather confounded with the brilliancy which depicts it strongly in our eyes; it may therefore be considered as a specific character. White is the most common colour of the metals, but there are also yellow and red. The former were distinguished by the name of the lunar metals, because silver, or luna, which was placed at the head of these metals is a white colour; and the second were denominated solar metals, because of the yellow colour of gold, which bore the signature of the sun. By a more accurate examination of the metals as to their colour, we find them grey, as in iron, molybdena, tungsten, uranium, manganese; blueish as lead and zinc; yellowish as bismuth; reddish-grey, cobalt; reddish-white, nickel. Though the colour be

## 18 CLASSIFICATION OF METALS.

permanent in the metals, while they themselves are supposed to be in a permanent state, it nevertheless is very easily changed in those bodies by the slightest combination.

25. Density of mass, or quantity of matter contained under a given volume; whence the specific gravity that results is greater in the metals, than in any other natural bodies. It is concluded, that their particles are nearer to each other, and that their pores are smaller than can be imagined in any other bodies. This density is the cause of their brilliancy.

The metals when compared by this property, stand with regard to each other in the following order, supposing pure water, to which they are all compared to have the

Specific gravity,	1,00
Platina	20,85
Gold	19,258
Tungsten,	17,6
Mercury,	13,568
Lead,	11,352
Silver,	10,474
Bismuth,	9,822
Nickel,	7,807
Cobalt,	7,811
Copper,	7,788
Iron,	7,6
Tin,	7,291
Zinc,	7,19
Manganese,	6,85
Antimony,	6,702

Uranium,

Uranium, 6,44

Arsenic, 5,763

The specific gravity of molybdena, titanium, chrome and tellurium are not known.

26. The hardness of the metals varies frequently in those which are ductile, because their parts may be brought nearer together by different degrees of pressure. It does not vary in those which are brittle. It is often less than that of the stony fossils, since these reduced to a powder grind their surfaces, and serve to polish the metals. It is therefore evident that this property does not follow density, and that it depends on the integrant particles, and not on their vicinity to each other. This property is estimated or determined by the manner and the difficulty of polishing the ductile metals, as well as by the effect of a blow on the brittle metals. By comparing them it is found that eight degrees of hardness may be exhibited by an arrangement of the metals, and that beginning with those which possess the property in the highest degree we shall place,

In the first rank, iron and manganese,

In the second, platina and nickel,

In the third, copper and bismuth,

In the fourth, silver,

In the fifth, gold, zinc, and tungsten,

In the sixth, tin and cobalt,

In the seventh, lead and antimony,



## 20 CLASSIFICATION OF METALS.

In the eighth, arsenic, the most brittle, in fact of the brittle metals.

Mercury being constantly fused, cannot be compared with respect to this property. The comparative hardness of titanium, uranium, molybdena and chrome is unknown.

27. The elasticity in metals appears to follow the same order as the hardness.

28. Ductility, is one of the most important, and most useful physical properties of the metals, and belongs exclusively to these bodies. Its name is derived from the habitude of these bodies, to suffer themselves to be led or drawn beneath the hammer, the pressing-cylinder, or through the wire-plate. It is caused by the metallic particles, sliding over each other without diminution of their adhesion, when this effect is produced by pressure. A kind of variety is remarkable in the ductility of metals. Some in fact, are much more capable of being flattened than drawn out, as lead and tin, and others in the contrary state as iron. It is thought, that this depends on the form of the particles, and the nature of their aggregation. The malleable, and laminable metals seem to be composed of small plates, and the malleable metals of fibres placed one beside the other. The one slide by their flat surfaces, the other lengthen, and adhere end to end. When the metals are compressed, caloric is expressed or driven out from between their particles, and they

they become hot. The more these are condensed, the more hard and elastic they become, with an increase of specific gravity, at the same time that they become more stiff and brittle so that they crack, and are broken asunder. This last property is denominated hammer-hardening. Ductility and softness is restored to metals by heating them, and this operation when applied for the specific purpose here mentioned is called annealing. Though we cannot really compare the ductility of metals excepting in those which are not brittle, it will not be impertinent to assign respective rank to them in the order of this property, to determine the degrees of brittleness. Beginning by those which are most ductile, and descending to the metals, which are the most brittle, the following arrangement must be admitted :

Gold,  
 Platina,  
 Silver,  
 Iron,  
 Tin,  
 Copper,  
 Lead,  
 Zinc,  
 Mercury,  
 Nickel,  
 Tungsten,  
 Bismuth,  
 Cobalt,  
 Antimony,

Manganese,

Manganese,  
Uranium,  
Molybdena,  
Titanium,  
Chrome,  
Arsenic.

It must be remarked, that the arrangement of the eleven last metals, all of which are brittle, is not as well determined, as that of the real ductility of the nine preceding; that nickel seems to approach somewhat near to the same ductility of zinc; that some authors even place it before this last with regard to that property, though I do not think them well founded in that assertion, and that the metals most recently known, molybdena, titanium, uranium and chrome, have not yet been sufficiently examined, nor perhaps sufficiently purified to admit of the order I have assigned to them, being considered as definitive.

29. The word density, expresses the cohesion of the metallic particles with each other. As this property is of great importance in the arts, it has long been measured by means of metallic wires of the same diameter, at the extremity of which, weights are suspended untill the wires break. The wire is fixed by its superior extremity, and drawn by the inferior to which the weights are attached.

We cannot estimate this force, but upon the seven metallic substances, which are capable

ble of being drawn into wire. They must be arranged in the following order :

Iron,  
Copper,  
Platina,  
Silver,  
Gold,  
Tin,  
Lead.

30. I give the appellation of conductivity to that property which metals possess, of suffering caloric to pass rapidly between their particles, and consequently to deprive other bodies speedily of their heat, and to communicate it equally to those which touch them when they themselves are heated. Experiments of sufficient accuracy have not been yet made respecting this property, to enable me to offer in this place, the relation which would present itself between the different metallic substances. It appears to follow a particular law in the metals, and is frequently in a proportion, if not opposite, at least very different from that of the fusibility.

31. The dilatability by caloric, ought to be ranked among the physical properties. It consists only in the simple separation of the particles of metal by those of caloric which interpose, and accumulate themselves between these particles, and at the same time diminish their adherence, and their attraction. As it does not alter the chemical properties of these bodies, and is in truth, only a physical action,

con-

consisting only in a commencement of change of state with regard to metallic substances; as this property possesses many useful relations to the arts in which metals are employed, and is of consequence, that it should be well known, it would be of very essential service to the industry of man, if it were positively determined; but this has not yet been performed with the accuracy that might be wished. We know that it is sensibly proportional in each metal to the augmentation of caloric between the limits of the graduation of our thermometers; but at the approach of ignition the dilatation follows a law, much more rapid than the elevation of temperature, because the expansive force of caloric being then only weakly balanced by the mutual attraction of the metallic particles, is almost totally employed in separating the particles from each other. In order to estimate the dilatation of the metals, the ratio of this dilatation, according to one denomination, being given by the experiment for one degree of the thermometer, the fraction which represents this ratio, is multiplied by the number of degrees to which the temperature has been raised. This product must be squared, if the dilatation of surface be required, or cubed, if that of bulk be expected, and those relative expansions in a given magnitude of metal, may be easily applied to individual quantities in order to obtain the absolute

solute quantity of dilatation in any required instance.

32. Fusibility, like the last mentioned property is truly of a physical nature, since it is nothing more than the effect of dilatation, carried to that degree in which the expansive force of caloric prevails over the mutual attraction of the metallic parts, so as to admit them to move freely in every direction amongst each other, and to yield to the slightest pressure. We must not consider it as a combination of caloric with the metals, because the fusion ceases when the caloric is disengaged, and because it is necessary, that the supply of caloric, should be continually kept up in order that fusion may take place. This property varies singularly in the metals, and each of them may be heated to very different degrees before they flow. As the temperature to which they rise at the moment of fusion, cannot always be measured or indicated by thermometers, it has been determined in the following table by Citizen Guyton, as well according to the graduation of Reaumur, as the pyrometric scale of Wedgwood. The want of fusion in arsenic, which is more volatile than fusible, could only be estimated by approximation, and those of molybdena, tungsten, uranium titanium, and chrome, which are very difficult to fuse in general, resemble platina in this respect.

Fusibility

Fusibility deter- mined by the thermometer of Reaumur.	{	31	—	0	Mercury,
		0			Tellurium,
		168	+	0	Tin,
		205	+	0	Bismuth,
		296	+	0	Zinc,
		345	+	0	Antimony.
Fusibility deter- mined by the pyrometer of Wedgwood.	{	27			Copper,
		28			Silver,
		32			Gold,
		130			Iron, nickel, cobalt,
		160	+	+	Platina, man- ganese.

33. Volatility is the consequence, and as it were the extreme of fusibility. When the particles being as far removed from each other by the expansibility of caloric move freely amongst each other, if still more caloric be accumulated between them they separate more, become fused in that substance, partake its elastic fluidity, and rise in vapours which are condensed in proportion as the caloric which is only interposed abandons them. We might imagine that this property should obey the fusibility; but though it has not yet been exactly estimated, we must not consider the one property as regulating the other. It was formerly asserted, to be the character of the brittle metals or semi-metals to be volatile. We may observe, that arsenic, which is much more volatile than fusible, occupies the second rank in this respect after mercury; that bismuth and antimony immediately follow; that tin  
and

and lead so much more fusible than the latter are yet volatile only with extreme difficulty, and that a strong fire is required to volatilize copper, silver and gold, metals of a middle fusibility as was formerly observed. An extreme heat is required to reduce iron, and the other less fusible metals into vapour.

34. Crystallizability consists in the tendency of the metallic particles when separated from each other by their fluidity, to approach each other by surfaces best adapted, and to assume by their arrangement a regular form concerning which we have already treated in the second Section of the present work. When the metals after fusion are suffered to cool very slowly, and the congealed surface is broken, we find under the inner portion which still remains fluid, after pouring the portion off, crystallizations of various degrees of regularity depending on the regular tetrahedron or cube, which is the form of their integrant particles. We shall observe the varieties which this double form produces in the history of each metal.

35. All the metals eminently possess the faculty of conducting electricity, in consequence of which they are used in a multitude of electrical experiments. It appears that galvanism, or the property of exciting convulsive motions in the muscles, by interposition of two different metals, brought near each other after having caused them to communicate with  
and



## SECTION IV.

*Concerning the Natural History of the Metals.*

38. NATURE presents the metallic substances on the surface or in the interior of the globe. They are either alone or combined with different matters. These last combinations are called ores. They are deposited in beds more or less continuous between the beds of stones and earthy salts, where they form what is called veins. The part which covers them is called the roof, that which supports them the floor, and the collection of stones or crystals which accompany ores, constitutes their gangue or matrix.

39. Veins are distinguished into rich or poor, head veins or sprigs, true veins or cross veins. The terms rich and poor applied to the veins of ores explain themselves; the head veins are in large masses, which will pay well for the working; the small veins are scattered or dispersed and do not deserve working. They are only followed occasionally, in order to find the head vein from which they branch. Direct veins are those which follow the same direction, and may be easily pursued. Cross veins are those which are interrupted or broken, and seem to lose their continuity.

40. The

40. The name of ores supposes the metals to be combined with some foreign substances which marks their properties, and has been denominated the mineralizer. For the same reason, metals in this state are said to be mineralized. It often happens that two or more metals are united at the same time to the same mineralizer; and frequently, one single metal is at the same time combined with various mineralizers, and still more frequently are there in ores, all together a number of metals and mineralizers.

41. The metals and their ores are usually found in ancient primitive mountains of granite, gneis, quartz, between the beds of which their veins flow either in horizontal, oblique, or inclined directions. The latter is the most frequent: so that the head of the vein almost always appears out of the earth, or to the day, and by that means gives a certain indication of its presence. The pretended bad state of the trees, the dryness and want of vigour in plants, the hard and dry sands are but uncertain indications of ores. The pretended inclinations and rotations of branches of trees supported on the fingers, and which are called divining-rods are mere tricks of knavery and quackery, as are likewise the tremblings, convulsions, and indispositions pretended to be suffered by certain men who in that manner impose upon human credulity. The coloured and metallic sands, fragments of the ores attached to mountains, rolled down in

the plains, waters charged with certain metallic salts, and lastly, the boring instrument, are the only sure indications, which deserve the confidence of those who search after metallic bodies.

42. Besides the ores of original formation concealed in the bowels of mountains, and which, crossing them in veins, seem to have been poured at one single cast at the very time of the formation of these mountains, we find some minerals deposited in secondary strata, in masses, in stalactites, incrustations, crystals, in mountains or hills of modern formation, where they fill subterraneous clefts and cavities. These are manifestly owing to the operation of water, and the transport of matters altered, dissolved, modified in their passage. The oxygen of the former veins is not so well understood, though it is also attributed to water.

43. The numerous discoveries which have been made in the last half century respecting the nature of ores, and the several most modern analyses which have much enlightened and simplified our knowledge, respecting which, there were still many errors and hypotheses before the later labours of Bergmann, Klaproth, and Vauquelin, permit us at present to class these natural productions, or to reduce the various states of fossils to five classes, namely,

- a.* Native metals,
- b.* Metals alloyed together,
- c.* Metals united with combustible bodies,
- d.* Oxided

d. Oxided metals.

e. And lastly, metallic oxides combined with the acids

44. The ridiculous name of virgin metal was formerly given to those which are at present more accurately called native metals. This first class includes metallic substances which are found in the earth, in possession of all their characteristic properties, brilliancy, colour, form, weight, ductility, &c. Platina, gold, silver, copper, mercury, bismuth, antimony, and arsenic, are frequently found in this state, iron more seldom, and tin, lead, zinc, &c. still more seldom. To this class are referred those metals which in their native state are alloyed only with small quantities of other metals, so as to occasion very little alteration in their obvious properties.

45. Metals alloyed together without any other combination, and without union with combustible bodies, are much more scarce in nature than might be imagined. Gold and silver, gold and copper, mercury and silver, are only found in this state.

46. The natural combinations of metals with combustible bodies, are on the contrary, much more numerous and more multiplied. We might even say that it is in this state, particularly in that of metallic sulphurets, that nature has created them. These sulphureous compounds form the veins of ores, or those continued masses with which the mountains are intersected. These

veins are most commonly explored by man, and from these, the greatest quantity of the metals used in society, are obtained. Such, more especially, are the ores of lead, copper, silver, zinc, mercury, antimony, &c. It is not improbable, but that other combustible bodies, carbon, and particularly phosphorus, may be discovered as mineralizers of metallic substances.

47. The metallic oxides are also very abundantly spread over the face of the globe. But they are never found in such large masses as the sulphurets: they have long been considered as metallic earths, because they have an earthy appearance. They are the product of the primitive veins penetrated, carried off, and transported by water; and are found in mountains of secondary formation. The oxides are usually rich in metal, and easy to be treated. In this state more especially are found copper, iron, lead, zinc, antimony, and all the brittle metals. Platina, gold, and silver are the only metals which are not found native in this form.

48. Lastly, the saline metallic combinations, or compounds formed of metallic oxides, united with acids or the simple radical, likewise form, if not the most abundant ores, at least, those which nature presents most frequently, and in the most various states. Native sulphates and carbonates, of copper, of iron, of lead, of zinc, the muriates of most of these metals, and of mercury, the phosphates of lead and of iron, the arseniates, the

the molybdates, the tungstates, and the chromates of metals are all found in the native state. These last four are particularly formed by the oxides of the brittle metals: sometimes in beds, in depositions, in stalactites, in incrustations. Sometimes they crystallize in subterraneous cavities; frequently, they are dissolved in water, but they are never found in masses like the sulphurets.

49. The value of metals in commerce, and the profit they afford to those who possess them, proportioned to the rank which they occupy in the estimation of man, have frequently caused names to be given to ores which very inaccurately represent their true nature. Thus it is, that the denomination of ores of gold and silver, or of copper is given to such ores as really belong to other metals, with respect to the proportion of metallic matter they contain, though they afford a sufficient quantity of gold, silver, or copper to defray the expences of working with advantage.

50. This mode of denomination has caused much trouble and confusion in mineralogy, and, though several authors have in this respect, adopted the nomenclature of the miners who consider only the value of the product, and not the proportions of the component parts, it is evident, that mineralogists ought to follow a contrary course, and refer each ore to the metal which it most abundantly contains; for it very often happens, that minerals contain five or six

## 36 NATURAL HISTORY OF METALS.

different metals, united at the same time to one or more mineralizers.

51. There are consequently, three different manners of distinguishing and classing metallic ores. One, that of miners, which has respect only to the precious metal which is afforded. This is not the method, but simply the usage of workmen who express the aim of their labours, or the end towards which they are directed. It cannot but be hurtful to the progress of science, when applied as the language of classification. The second consists in referring each ore to the metal with which it is the most charged, and consequently, to follow in their classification and distribution the series of the metals. We shall make use of this method in the history of each metal. The third, by considering the ores almost abstractedly from the metals with which they may be loaded, and considering them only as natural compounds, disposes or arranges those according to the number and the proportion of their principles. This general and truly mineralogical method may serve to class regularly the mineral productions of nature. A sketch will be presented in the section next following the present.

## SECTION V.

*Concerning the Art of Assaying Ores or Docimasy.*

52. BY successive labors in the art of assaying ores, or the analysis of the natural combinations of metals with the different substances which mineralize them, we have succeeded in distinguishing these compounds, in classing them, and in referring them to the metals to which each belongs. Without this art, no physical property or apparent character could have guided men to this distinction, and the knowledge of ores would have remained in that state of uncertainty, error and imbecility in which it so long languished before the researches of modern chemists.

53. Ores were at first assayed with the simple view of ascertaining the advantage which might be derived from them, the nature and quantity of metallic substances which might be expected, and to guide miners in the works they might undertake, and devote to the exploring each kind of ore. This intention was not in the early times directed to the accurate analysis of minerals, or to ascertain with precision the nature or order of their component parts. The only views which at first animated chemists, were to ascertain the proportion of metal they  
con-



tained, the facility and difficulty of extracting it, and to compute the loss and charge which that operation might require. Thus far the docimastic art was confined to the simple practice of the miners. But skilful chemists having been frequently consulted respecting this art, and the great varieties observed in different modifications of the same metal, having struck those who were charged with their examination, the docimastic art soon advanced towards perfection, and has become one of the most important branches of chemistry. Its results are no longer confined to the mere metallic products; they are extended to the different matters which mineralize metals, their proportion, their adhesion, their attractions, and their various modifications or habitudes.

54. The art, therefore, being elevated to new conceptions, became connected with mineralogical science. It is an essential part of this branch of natural history, to which it has given a great degree of perfection. We are led, therefore, to distinguish docimasy into two parts, the one which is directed merely to enlighten metallurgy, so as to precede and direct its processes; and the other, which considers its subject in a greater extent, and not only applies to the research of the metal, and the means of extracting it with the least trouble or charge, but also proposes to determine with accuracy the materials of the ores, to compare them together, and to furnish the means of systematically  
arrang-

arranging them. The aim of the first is to direct metallurgic practice; the other while it answers the same purpose, is also advantageous to the mineralogist who is desirous of classing metalliferous fossils, and the geologist who desires to know their formation, their changes, their transitions, and respective relations in nature. The chemist must consider docimasy in this double point of view, in order to form a proper conception of the properties of metals.

55. Though the docimastic works in general may be considered as really different, according to the ores upon which they are employed, they nevertheless, have one common resemblance under which we may consider the process as an operation nearly analogous with all minerals, at least, as far as relates to the art of the miner. The specimens of the ore are first selected out of the rich, the poor, and the middling samples: this is called lotting it. These are pulverized, are broken in a wooden stamper, to deprive them of their light stony matrix, and collect the mineral at the bottom of the vessel. They are roasted in a shallow earthen vessel, with a proper cover to prevent loss by decrepitation; by this treatment, the volatile part of the mineralizer flies off in vapour in the atmosphere, and the metallic part becomes oxidized. The ore is left ignited till it emits no more perceptible vapour. The weight after this roasting, shows the proportion of volatile matter it contains. The roasted ore is afterwards mixed with three times  
its

its weight of black flux or tartar, half burned by nitre, and a small quantity of muriate of soda. The carbon of the flux thus oxides the metal. The alkali causes the matrix to flow, and the sea-salt covers the metallic substance, and defends it from oxidation. When the fusion is complete, the mixture is suffered to cool, after which, under a well-fused and very homogeneous scoria, the metal is found collected in a single mass, of which the weight and the nature indicates what may be expected by metallurgic work in the large way.

56. The assay often requires to be modified in certain respects according to the different nature of the ore.

In some cases, more active fluxes than the black flux are required, particularly for the more refractory or more infusible ores. In that case, borax or pounded glass with pot-ash is taken, and frequently, oil or tallow is added to favor the reduction of the metallic oxides. Sometimes, even the elective attractions are employed to unmineralize the metal by heating the ore with another metal, which has a stronger attraction for sulphur than that metal has which is contained in the ore. But it seldom happens in cases of this sort, that a portion of the metal employed does not combine with that which was added, so as to alter its quantity and quality.

57. The metal obtained by this first process is seldom pure. A metal difficult to burn, such

as was formerly called a perfect metal, frequently contains a very oxidable, or as it was called, imperfect metal. In that case, to abstract this last, the metal is roasted a second time, heating and agitating it with the contact of air; and though this process has not an extreme accuracy, it is sufficient, nevertheless, to afford a result suitable to the expectations of miners. This method of assaying is even too accurate, in some instances, for the necessities of metallurgy; for it gives a greater metallic product than can be hoped for in the large way, and produces an error, because it requires the use, and is made under the influence of fluxes which cannot be applied in the operations in the large way: for this reason, the assay is made to resemble the metallurgic works more closely by attempting to flux the ores simply among charcoal, and the fusion is assisted by iron scales, or glass-gall; matters of such low price that they can be employed in the large way.

58. Though the assay may be sufficient for the miner or metallurgist, those who cultivate mineralogy and chemistry are not content with it, because it does not afford the information they require for the knowledge and classification of minerals. Part of the metal escapes in vapour, part remains in the scoria; the metal itself is more or less impure, and its ore is dissipated or confounded in the scoria. To this irregular assay, we must, therefore, substitute an analysis, accurate in all the means which art can

can employ. The imperfect roasting of the metallurgist must give place to the regular distillation with the retort, or the action of fire enclosed in vessels in such a manner as to collect the solid; the liquid or aeriform products, disengaged by caloric, to ascertain their nature and determine their quantity, at the same time, that a proper estimate is made of the fusibility of the ore, after having carefully described its form, structure, colour, specific gravity, and all its physical properties.

59. The most severe and most useful method of analysing ores, or to make a complete chemical assay, consists, more especially, in treating them by acids which dissolve the metals without touching the mineralizer, particularly sulphur. For this purpose, however, we must use the sulphuric or muriatic acids, for the nitric, particularly when too strong, forms a sulphur, and produces error respecting its quantity, and even frequently changes the nature of the ore. The sulphuric or muriatic acids must also be diluted in almost every case. The insoluble matters being well washed, indicate the proportion, as well as the nature of the mineralized substance. The metal in solution is precipitated by alkalis, by hydro-sulphurated water, and often by other metals, which having a stronger attraction for oxygen, disengage it, and separate it from the acids, in which they take its place. In general, it is easy to observe, that in this kind of analysis, which is here pointed out only  
in

in a general way, an extensive and entire knowledge of the action of all bodies on the several metals, is supposed to be in possession of the operator. For all bodies, when once their action is well known, may become very useful instruments in the analysis of ores. Numerous proofs of this will be seen in the history of each particular metal.

## SECTION VI.

### *Concerning Metallic Works on a large Scale, or Metallurgy.*

60. WHEN it is once ascertained by the docimastic effect, that an ore may be worked with advantage, the metallurgist proceeds in his operations, first extracting the ore by all the mechanical methods the art possesses, which consist in digging shafts, opening adits, employing various machines to raise the water, renew the air, bring up the ore, favor the ascent and descent of the miner, prevent the earth from giving way, &c.

61. These first processes of the extraction of the ore, enlightened by the information of geometry, mechanics, mineralogy, geology, subterranean geometry, founded also on the knowledge of constructions of frame-work in wood, requiring the united exertions of various talents, and supported by courage, patience, and firmness  
in

in enterprize, constitute a very important art which requires long and serious study, continual observation, experience, and practice, added to the most profound theoretic meditations. A man thus qualified is an engineer of mines. Though, this art may appear foreign to the general study of chemistry, it is necessary that the student should be acquainted with its first notions or elementary parts, which necessarily precede the knowledge of the metallic treatment of ores. The following are the bases of the art of extracting them from the earth :

62. In general, after having bored the ground which contains ores, or having ascertained their existence by various indications, a square perpendicular well, or shaft is dug in the ground, sufficiently wide to place strait ladders therein ; over which machinery is fixed for the purpose of raising and lowering vessels, and in which it is sometimes necessary to fix pumps to draw off the water which is collected. If the ore be too deep for a single shaft to lead from the grass or surface, to the vein at the bottom of the first shaft, an horizontal gallery is opened, at the end of which a second shaft is sunk, and in this manner the workmen proceed until they arrive at the bottom of the mine.

63. When the rock to be perforated is hard, solid, and capable of supporting itself, the shaft will not require to be guarded within, but if it be soft and friable, if it threaten to  
fall

fall in during the excavation, it becomes necessary to support the shaft and gallery with pieces of wood-work, covered with planks all round, in order to support the earth and retain the fragments, which from time to time would separate and might maim the workmen.

64. One of the important particulars of the art of exploring mines, is the renovation of the air. When it is practicable, to open a gallery which shall lead from the bottom of the shaft to the day or open air, a current is easily established by this simple artifice. When this is not possible a second shaft is sunk to the extremity of the gallery, opposite to that where the first was sunk. When one of these shafts opens at a different level from the other, the circulation and renewal of the air are easy. If the second shafts be of equal height, the current will not take place spontaneously, but must be determined by causing of them to communicate with a lighted furnace.

65. The danger of waters which overflow the works, and retard the operations, at the same time that they threaten the safety of the workmen, are no less necessary to be provided against. If the water transudes gradually through the earth, it may be let off into the plain or the nearest river by means of an horizontal adit. If it be collected in greater quantity, or if it be not possible to open such an adit, the water is extracted by pumps, which are moved either by a stream, or by a pond, or by vapour of water



water introduced, and condensed in cylinders. These last machines called steam-engines, are at present much more common than formerly. It is an object of great difficulty sometimes to defend the works against enormous masses of water which rush forth when in digging a vast subterranean reservoir is opened. These cases happily are very rare, but they are in some measure provided against by a kind of movable strong door, or barricado, which the workmen place at the moment when they find by the particular sound of the rock, that the waters are coming in upon them, which barricado, by separating them from the liquid, gives them time to save themselves.

66. The destructive elastic fluids, which so frequently are disengaged in the cavities of mines, and particularly the carbonic acid gas, and different species of mixed hydrogen gasses, more or less pernicious, are also among the most formidable enemies of miners. Galleries, fires, ventilators, inflammations by means of torches held at a great distance in those parts of the mines which are mephitized by the inflammable gasses, and particularly the various methods of causing fresh air to enter, are the only remedies which can be opposed to these subterraneous evils.

67. When the ore which has been discovered and extracted from the ground by pick-axes, crows, gun-powder, &c. is carried to grass, it is subjected to all the mechanical and chemical

cal operations requisite to separate the metal. These operations necessarily consist in sorting, stamping, washing, roasting, fusing and refining. Though each of these six metallurgic operations, differ more or less according to the nature and kind of the ore, they are nevertheless all more or less necessary to each other, and they have in every species and locality, and under every variety of manipulation always some common circumstances which allow them to be described in a general manner.

68. Sorting consists in the separation which is made after the ore is brought to grass, or to the surface of the ground, of the different pieces of ore, which frequently require different modes of treatment, or are expected to afford different products according to their riches and their nature. It is not practised excepting in rich and valuable ores, such as those of gold, silver, &c. It is entrusted to a skilful workman, or men well experienced in mine works, one of the master miners.

69. When the ore is sorted, it is carried to the stamper. This is an instrument for pounding, a kind of large mortar or trough, in which, by means of wells, vertical pieces of wood are moved up and down, terminating below in an iron surface rounded like the end of a pestle. The alternate rise and fall of these kind of pestles moved by water, air, or fire, break, and pound the ore, together with its gangue.

70. From

70. From the stamping mill, the pounded ore is conveyed to the washing, which is performed by many different operations, either by hand in wooden vessels, or in troughs, which cross a current of water, or on the bank of a brook, or even in its bed, or upon inclined tables armed with cloth, intended to stop the irregular fragments of the ore; this last machine is not used, excepting when the ore is rich and valuable for the abundance of its metal. In all these processes, the agitated water carries with it the stony matter which is lighter than the ore, while the ore itself falls to the bottom of the utensil in which the washing is performed.

71. The operation of roasting renders the ore friable, divides it and reduces into small pieces, or separates by volatilization the greatest part of the mineralizer, which conceals the properties of the metal. It is performed in a variety of ways or different processes, according to the nature of the ore, the force or extent of fire intended to be applied, the degree of adhesion, and quantity of mineralizer, whether sulphur or arsenic, and sometime both together, which are intended to be separated. The roasting is sometimes performed in the air, sometimes in furnaces, or among the charcoal; in some instances there are particular furnaces for this operation, and in others the same furnaces as are intended for smelting, are also used for roasting.

72. Smelting

72. Smelting, or the art of fusing the ores after roasting, is the principal and most important of metallurgic operations, all the other being preliminary or preparative to this. The whole attention of the miner is directed towards this process; to this all his efforts are applied, because it affords the true useful product to which his hopes are directed. Though it consists in general in fusing the roasted ore to extract the metal; though in this point of view it seems to present a simple and uniform operation, there is, nevertheless, no operation which differs so much in its circumstances, according to the nature of the metal and the ore required to be treated, and according to the furnaces made use of, the nature and quantity of the combustible employed, the energy, duration, and administration of the fire, the addition of an appropriate flux, the heat being applied in the midst of the coal, or in crucibles, the period, the length of time, and the mode of casting the fused metal; every thing, even the form of the metal which flows out, varies, and presents to the observer very remarkable differences. On this subject we shall speak more largely under the history of each particular metal.

73. When the ore is smelted, and the metal obtained, the whole process is not yet finished. This metal is scarcely ever pure. It is either altered by certain substances foreign to its metallic nature, or it contains a portion of another

metal, which alters the properties of this which is desired in a pure state; or else it contains a portion of a metal more valuable than all the rest of the mass, which it is necessary therefore to extract; or, lastly, it is an alloy, in large proportions of several metals, which are required to be separated from each other. These various objects to be fulfilled, of which the practice must differ, as we perceive from the simple enumeration, belong to the last operation of treating ores in the large way. All the operations subsequent to the smelting, are comprehended under the general name of refining, because the effect is always to obtain a pure metal. Under each article of the several metals we shall show what are the practices respectively for refining the same.

## SECTION VII.

### *Concerning the Oxidability, or Combustibility of the Metals by the Air.*

74. ALL that has hitherto been said respecting the metals in general, is but remotely applicable to their chemical properties, or at least it requires the study of these last properties, in order to receive a more accurate development, and to present the most precise results to the understanding. It is therefore essential to fix our attention upon these last properties in order to obtain the characters of metallic substances.

The

The six last paragraphs of this history of the metallic genus are consecrated to the examination of these properties. We pass successively in review the manner in which they are altered by the air, their combination with combustible bodies, their action upon water and the oxides in general, that which they exercise upon the acids, their habitudes with salifiable bases, and lastly, with the salts. These six divisions will complete all that can be known respecting the chemical compositions of the metals; and we shall see that the same order, followed with some modification with regard to the species, will render their history equally accurate and complete.

75. When we separate the oxidability of metals by the air, or their combustibility, properly so called, from all their other chemical properties, we announce that this property deserves a most marked attention. It is in fact the most prominent fundamental character, the most important attribute of the metals; it is at the same time the key for explaining all the phenomena they present in their combinations. The oxidability of these bodies by the air, varies not only with regard to their species, as we shall see in the history of them respectively; but they also vary,

*A.* With regard to the temperature at which the combustion is effected.

*B.* Or the facility with which it takes place.

*C.* Or the difference which the temperature itself undergoes during the process.

E 2

*D.* Or

*D.* Or, by the proportion of oxygen it requires.

*E.* Or the phenomena which accompany it.

*F.* Or the various attractions of the oxidizing principle to the metals.

*G.* Or the state of the oxygen in the oxidized metals.

*H.* Or, lastly, by the character which the metallic oxides assume in proportion as they acquire that state. In order to obtain accurate notions of these circumstances we must consider each of them by itself.

76. The oxidability of certain metals by means of the air, commences at the lowest temperature, but in other metals it requires the most extreme heat. Manganese, and iron, for example, burn at all temperatures; silver, gold, and platina, on the contrary, do not burn unless extremely heated. All the other metals hold an intermediate place between these two extremities. On this account it is that the oxidation of metals, being formerly considered as a kind of destruction, because in this process they lose their metallic properties, and undergo a great diminution with regard to the arts, chemists have considered gold and silver as indestructible metals, and iron, on the contrary, as the most destructible of these substances. But it is evident, that this is only a specific difference between them, that it truly relates to the time proportionally required for their oxidation. For there is not a single metal which, when exposed

for a sufficient time to the air, does not at last undergo combustion by the mere temperature of the atmosphere.

77. The facility of oxidation is the consequence of the preceding property. Some metals burn, and become oxidized so easily, that it is necessary to defend them from the contact of the air, if we wish to preserve their brilliancy and their solidity. Such are iron, tin, lead, copper, manganese, which cannot be well defended from change by the air but by covering them with a varnish or a metallic coating of some other kind. On the contrary there are metals which undergo scarcely any change, even in their polish, such as gold and platina.

78. The metals differ in their oxidability, not only with regard to the manner in which they respectively demand an elevation of temperature, but there is with regard to most of them, a diversity even in the mode of their oxidation by which the difference of temperature they are exposed to may be marked. In general, they all tend to become oxidized more easily on the one part, and to absorb their oxygen on the other, the higher the temperature is to which they are exposed. And still more do most of the metals become oxidized in a determinate manner, and at any determinate temperature, whence we may appreciate the state of their oxidation by the heat which has been communicated to them.

The



The elevation of temperature in the metals almost always causes rapidity of oxidation, and elevates this property even to inflammation, or the evident phenomenon of combustion. Thus it is that when fine filings of the metals are thrown into a stove in a strong state of ignition, or through brilliant flames, they form, while burning, sparkles of a lively and shining appearance, depending on the strong heat they undergo; and from the same cause it is that iron or steel, strongly struck against siliceous stones, burns with a lively flame in the air, in consequence of the great heat which this percussion communicates to them.

79. The proportion of oxygen which unites to the metals during their oxidation, is also one of the circumstances which cause the variation of this phenomenon. They all differ with regard to this proportion, and, consequently, demand a greater or less contact of the air, in order that they may be burned. Each metal likewise varies in itself as to the quantity of oxygen it absorbs in the air, according to the manner in which the combustion is performed, and the temperature to which it is raised.

80. In all the limits of the condition and circumstances which have been here mentioned, the phenomena of the oxidation of the metals are different. Sometimes the metal ignites and takes fire; sometimes it is oxidized without fusion, or, in other instances, the metal does not oxidize until after it has been fluid. Sometimes it becomes

becomes covered with a thin brittle crust or adherent powder; in other instances a pellicle of rainbow colours is formed at its surface to which the oxide does not adhere. But in every case the metal becomes tarnished, loses its brilliancy and its colour, and assumes an appearance which announces the oxidation it has undergone.

81. Oxygen, by mixing in the metals in proportion as they burn by exposure to the air, either contracts an adherence, or unites with an attraction which is peculiar to each of them, and of which the degree is highly important to be known with regard to a multitude of operations and chemical results. On this degree depends the difficulty of separating the oxygen united to the metals, and the necessity of sometimes employing bodies which attract it still stronger in order to cause its separation.

82. We must also observe, during the fixation of atmospheric oxygen in metallic substances, the mode also of this fixation, and the state which the principle itself acquires. In some of the metals it is absorbed in a very solid state and loses much caloric; in others it is precipitated without abandoning the same quantity of its solvent; so that if the several metals be oxidized singly in the centre of the calorimeter, the quantity of fused ice may serve to determine the proportion of caloric disengaged from the air by each of them; and, consequently, the state of solidity which the oxygen contracts. This proportion  
answers

answers to the manner in which their decomposition or difoxidation may be effected, those which have absorbed oxygen in the least solid state, or retaining the greatest quantity of caloric, are reduced easily by caloric or by light; those on the contrary, in which the oxygen fixes itself with the loss of much of its solvent, are not unburned or difoxidized, or consequently reduced into the metallic state, but by a great accumulation of caloric. Most of the metals even require the addition of some other body which has a stronger attraction for oxygen than the metal itself has.

83. With regard to the characters which distinguish the metallic oxides made by the contact of the air, they are all varied in the different species, as we shall hereafter see; but they have at the same time certain properties common to all of them, by which they differ from the metals; and it is to these properties that we must in this place direct our attention. All the oxides possess the pulverulent form, or they are brittle, and easy to be reduced into powder. They present all the possible shades of colour, from white and grey to brown and deep red; they weigh more than the metals from which they are produced, and this augmentation amounts to a few hundredth parts in some oxides, and in others to more than half their weight; they resemble earths, and for this reason they were formerly denominated earths, or metallic calces. Some of them resume their metallic  
state

state by the mere contact of light, or caloric; others, without passing entirely to that state, approach towards it; others require the addition of carbon ignited by fire, which attracts their oxidizing principle; and there are some which seem to be incapable of reduction. Some of the oxides are fusible by fire, and afford gases more or less coloured, transparent, and serve even as fluxes to the earths; others, on the contrary, resist the most violent heat, and even injure the transparence of those glasses into which they enter as component parts. Some of the oxides are volatile, but most of them are fixed. Some of them exhibit an acrid and caustic taste, a solubility differing in degree in water, and even an acid quality; others have no taste or solubility. Some of the calces unite with alkalis like acids, but the greater number are soluble in acids, and saturate them after the manner of the earthy and alkaline bases. Some of them burn combustible bodies with flame, because they contain oxygen in a state slightly condensed; most of them, on the contrary, burn slowly, and without any appearance of inflammation.

## SECTION VIII.

*Concerning the Combinations of the Metals  
with Combustible Bodies.*

84. IN the second section of this work, mention has already been made of the union of metallic substances with combustible bodies. We shall therefore in this place only repeat a few of the general circumstances relative to these combinations, in order to render the history of the metals complete; and we shall insist upon some which have not yet been pointed out, or have been too rapidly stated, or such as were stated only for the purpose of placing the metals among the series of undecomposed combustible bodies, and comparing them to those which had before been treated of.

85. We have seen that the union of azote, hydrogen, diamond, and the metals, is not yet known. It is not, however, improbable, that these combinations exist; and that though they have not yet been found in nature, nor produced by art, this circumstance arises from the processes of chemical analyses and syntheses being still very far from the state of perfection necessary to form or to discover such compounds. We know, however, that hydrogen gas is capable of holding several metallic substances in solution, particularly arsenic, zinc, and iron. It has been discovered that the diamond combines very well with iron by fusion,  
and

and converts it into steel ; an effect which shows a still stronger resemblance of this combustible with pure carbon.

86. Though we are yet acquainted with only one combination of carbon, with a metal, we cannot doubt but that there must exist many others, and that most metallic substances are capable of uniting with this combustible substance. Nature probably forms these combinations, and the singular properties presented by iron in its union with carbon, prove there are many discoveries still to be made upon this object, which is of so great importance to mineralogy, geology, and all the arts relating to the metals.

87. Though we are unacquainted with any carbonated metals, or metallic carbonates excepting that of iron, we at least have known for a long time, that the metallic oxides universally undergo a more or less evident decomposition by carbon. This body seizes the oxygen of their oxides, burns either with flame, as happens with the red oxide of mercury at an elevated temperature, or slowly without flame. Carbonic acid is disengaged in the form of gas during this process and the metal is left in its metallic state. We can even determine by this decomposition, the proportion of oxygen contained in the oxides respectively, from the quantity of this acid obtained, and we can proportion with considerable accuracy the matters necessary for the complete reduction

of a mixture of carbon and metallic oxide to the double state of metal and carbonic acid without residue. The success of this last result obtained by Lavoisier, supposes that we should be well acquainted with the nature of the oxide, and the quantity of the oxygen which it contains; a portion of knowledge which is acquired by a previous operation in which we form an estimate of the quantity of carbonic acid afforded during the reduction.

88. The compounds denominated metallic phosphorets were formerly unknown. Pelletier obtained them with great facility by reducing the vitreous phosphoric acid mixed with the metals and charcoal, and it is also obtained by treating the metallic phosphates, with charcoal and a strong heat. I have elsewhere observed, that these compounds of which I suspect the existence in nature, though no experiment has yet exhibited them to chemists are but very slightly combustible in the air; that they are of a granulated texture with a brilliant metallic aspect; that they are brittle, fusible, and decomposable by strong heat. I must here add that most of the metallic phosphorets are decomposable by heat.

89. The metallic sulphurets presented by nature in such abundance, and under such multiplied forms constituting the most common ores, present, as their remarkable properties, whether in a natural or artificial state, de-  
com-

composition by a strong heat; easy fusibility with regard to the fusible metals, and a difficulty of fusion with regard to those metals which are more fusible alone; sulphatization by the contact of the air; analysis more or less easy by acids, which dissolve the metal, and separate the sulphur, and solubility with the formation of sulphurated and hydro-sulphurated oxide by the alkalis. We must also distinguish the metals which unite best with sulphur after having been oxidized, from those which combine with it without oxidation; their combinations with hydro-sulphuret, and their different attraction for sulphur, which permits chemists to decompose some of the metallic sulphurets by other metals; as for example the sulphuret of antimony by iron, &c.

90. The metals in general unite very well with each other, though there are several remarkable exceptions in this respect. These combinations are in general denominated alloys. Mercury in forming its alloys softens, and even dissolves most of the metals for which reason these alloys have received the particular name of amalgams. Five or six metals may even be united together, so as to form complicated alloys of which the arts in some instances make a great use, and which may be separated and examined by the docimastic art. A number of these metallic compounds are employed in the common purposes of life. When metals are united together by fusion they



they never preserve the same density and texture as before, nor the intermediate specific gravity which their proportions would afford by calculation. The alloys are always either more dense, or more rare than the sum of their primitive density would show. And they all possess new properties as to their fusibility, their capacity for caloric, their combustibility, &c.

## SECTION IX.

### *Concerning the mutual Action of the Metals, of Water, and of the Oxides.*

91. THE discovery of the decomposition of water has not yet been considered of as great importance as it really is. It has not been so highly esteemed as it deserves among the great discoverers at the end of the century just expired, with regard to the immense advantages it has afforded to the theory of the knowledge of nature. The history of the metals has acquired a multitude of explanations of phenomena which were not before comprehended, and would never have been understood, but by means of this important discovery, one of the most beautiful, and most surprizing, for which we are indebted to modern chemistry.

92. There

92. There are nevertheless, very few metals which possess the property of decomposing water alone, because hydrogen in the state of gas decomposes most of the metallic oxides, some without heat, and most of them by the assistance of caloric, which proves that this principle has a stronger attraction for oxygen than the metals in general have. To this fact we must add, that it decomposes the oxides of such metals as are even themselves capable of decomposing water, when they are in a state of oxidation, more advanced than that state in which oxygen seized from its union with hydrogen could carry them.

93. We must distinguish with respect to the action of metals on water, four classes of these bodies. Some decompose it without heat, and require no assistance for this purpose; a short time only is necessary for this decomposition. Thus it is, that iron placed in contact with cold water, requires several days to separate the hydrogen, and absorb the oxygen as we see in the preparation of the black oxide or martial ethiops of Lemery, made according to the first process. Zinc also belongs to this class, as well as manganese.

94. The second class includes those metals which not being capable of immediately decomposing water in the cold, become capable of effecting a change by a strong heat at the temperature of ignition. It is probable, that there are many more metals in this condition than  
has

has been imagined. Antimony and tin, in particular are of this order. We may easily imagine, that the metals of the first class acquire by an elevated temperature, the property of decomposing water much more strongly and abundantly than they decompose it in the cold.

95. To the third class, I refer those metals, which being incapable of decomposing water, either at a common or an elevated temperature, while they act alone upon this oxide of hydrogen, acquire this property by a predisposing action, which the acids, and in some instances, the alkalis exhibit by their tendency to unite with the metallic oxides. This property is found in copper, lead, bismuth, &c. The metals of the two former classes, when treated like those of this third class, act with still more energy in the decomposition of water.

96. In the fourth class, I arrange those metals which have not, either by simple attraction or by predisposing attraction, or any union whatever of attractive forces, the property of decomposing water; and which, consequently never afford hydrogen gas in any circumstances whatever of chemical combination. Mercury, silver, gold, and platina are the only metals of this class, and it is easy to observe, that this property agrees with the other circumstances; which are slight attraction for oxygen, and the facility with which this principle is separable from them.

97. This

97. This action of the metals upon water being once accurately determined, it becomes no longer difficult to account for the phenomena they present with the acids,—the strong effervescence, and the abundant disengagement of hydrogen gas which accompanies their solutions, the reduction of most of their oxides by hydrogen gas; and many other circumstances which were unintelligible, and incapable of explanation in all the periods of chemistry, that preceded the discoveries of the nature of water.

98. With regard to the oxides it does not appear, that there are any others of which the action on the metals in general requires to be determined, different from the actions of the metals themselves, since nothing has yet been seen or determined relative to the effect of the oxides of azote, of phosphorus, and of sulphur upon metallic substances. There are three general circumstances to be attended to between the metals and their oxides. The first relates to the re-action of these bodies on their proper oxides, in certain cases. Though it has been affirmed, that an oxide never unites with its own proper metal, and this observation is in general true, it is very remarkable, that if the metal be heated with its oxide in the utmost state of oxidation, it frequently happens, indeed, most frequently, that the metal assumes from its oxide, that portion of oxygen which adheres the least, or which was last added, and by that means partly dis-oxides it, and forms

VOL. V. F with

with it a kind of equilibrium of oxidation. Thus it is, that the red oxide of iron, heated with filings of the same metal, causes both the filings and itself to pass to the state of black oxide. The second circumstance depends upon the stronger attraction of the metal for oxygen, than that which the oxide exerts upon the same principle. In this case, the latter is dis-oxidized, the metal itself becomes oxidized, and sometimes even with flame, or more or less of light. Lastly, in the third circumstance, the metal added to an oxide, having less attraction for oxygen than the oxidized metal has no change whatever is found to take place between the two bodies.

#### SECTION X.

##### *Concerning the General Action of the Acids upon the Metals, and the Metals upon the Acids.*

99. SINCE chemists have treated of metals more particularly with the acids, because these agents have always appeared to them to be most capable of producing changes and characteristic alterations in them: since the combinations, they are capable of forming with these bodies, have been the object of numerous researches; and this part of metallic chemistry is most abundant with facts, as will more particularly appear

appear in the history of the metals individually taken. On the present occasion, we shall speak only of the general state of mutual phenomena exhibited by these bodies; and consequently, we shall not here examine this action as far as it respects each particular acid.

100. In the first place, we must in general observe, that no union takes place between the metals and the acids, unless these bodies be more or less oxidized. Accordingly, the metallic oxides which are soluble in acids, dissolve gently, and without effervescence; though the metals themselves are not soluble without commotion and effervescence. This last effect arises from the attraction of the metals for oxygen, being suddenly increased by the contact of the acids, and causes a disengagement of some other principle which takes the form of gas. This principle is afforded either by the acids themselves, or by the water. In the first case it may differ, according to the nature and state of the acid: in the second, it is always hydrogen gas, disengaged with more or less of alteration. Sometimes the two bodies, that is to say, the acid and the water, are at the same time decomposed by the metal, and then there is a disengagement either of two gases mixed together, or otherwise the two principles of these gases unite, and afford a new compound.

101. The metallic oxides cannot unite or remain united with the acids, unless they severally contain certain determinate quantities of oxygen.

gen. Short of those proportions, no union of these preparations takes place, and beyond them, they fall down in the form of precipitate. Each oxide, in particular, cannot even remain combined with an acid, excepting under limits of oxidation, which are, frequently, very precise. For this reason it is, that when metallic solutions are exposed to the air, or placed in contact with bodies capable of affording oxygen, they become turbid and precipitate in proportion as they absorb a greater quantity of that principle than they contained before. It frequently happens, even alone and in well-closed vessels, that the oxides thus suspended, re-act upon their acids by elevation of temperature, and the solution becomes turbid, and is decomposed by this spontaneous super-oxidation.

102. Those metals which have the strongest tendency to become oxidized by the action of the acids, cannot remain united with them, nor form permanent solutions. This phenomenon is particularly observable in the acidifiable metals, or in those of which the oxides are capable of uniting with the alkalis, and those metals also, which are more oxidable than soluble in acids, separate in the form of oxides at the bottom, their pretended solutions, and remain in a very small quantity, and for a very short time dissolved in the acids.

103. Metallic salts, cannot, therefore, exist but in the case where the oxides are capable of remaining united with the acids, and have no  
ten-

tendency to separate. They are not permanent excepting under those circumstances, wherein, their attraction for oxygen is not increased, or when that principle is not presented to them. The metallic salts have always an excess of acid, and are besides for the most part acrid, corrosive, and poisonous. In order to understand their properties, it is necessary, that we should examine, *a.* Their form. *b.* Their taste. *c.* Their alteration by light. *d.* Fusion, drying, volatilization, or decomposition by caloric. *e.* Deliquescence, efflorescence, or degree of decomposition by the air. *f.* Solubility in water, hot

or their alteration which is frequently ble by this liquid. *g.* Decomposition of salts and earths, the nature and properties of the oxides which these bases precipitate, the formation of triple salts which so often takes place in this decomposition. *h.* Alteration of the same oxides at the time of their precipitation, either by the action of itself, or by the air or by water.

*i.* Alteration by the various acids, their decomposition, or indecomposition, the effects of the attraction of the acids for the metallic oxides, and the changes these last undergo.

*k.* Action of the earthy and alkaline salts, whether it consist in a simple union, in a triple salt, or present a single, double, necessary, or superfluous decomposition. *l.* Mutual action of the metallic salts on each other, which is confined to the union of a sur-compound, the

double





double changes of the bases, and of the acids, or the displacement of oxygen, which precipitates with the oxides at once. *m.* Lastly, the alterations which combustible bodies, whether with or without heat, frequently produce. *n.* Dis-oxidation by heated carbon, those operated by the phosphorus, and the metals without heat; the precipitations by the sulphurets and hydro-sulphurets. After this examination, the history of a metallic salt is as complete as it can be.

104. The various metallic oxides not only possess different degrees of attraction for the acids, and consequently, must on that account influence the combinations they are susceptible of forming with those bodies; but the metals themselves, by the force of their attractions for oxygen, also produce very remarkable effects. Accordingly several metals are capable of depriving others of oxygen when they are plunged in a solution of these last in acids; causing them to re-appear under their metallic form, as is the case with mercury, which reduces silver, copper mercury, and iron copper. Sometimes, the metals deprive the oxides of only a portion of their oxygen, so that they are not precipitated in the metallic state, but merely in a state of less oxidation; thus it is, that tin precipitates gold in the form of a purple oxide, and not in its brilliant metallic state. This phenomenon is of the greatest importance in a number of technical operations.

105. After

105. After having shown the most general facts relative to the mutual action of acids and the metals; we must now observe the manner in which each acid exerts itself with regard to these combustible bodies, by considering in this place, the acids under the double relation of their peculiar natures, their composition, whether known or unknown, and their energy or general attraction for all the bases with which they are capable of uniting; that is to say, by disposing them in the following order, the acids, sulphuric, sulphureous, nitric, nitrous, phosphoric, phosphoreous, carbonic, muriatic, oxygenated muriatic, fluoric, and boracic. We do not here speak of the metallic acids, because they are not yet sufficiently known, and their history at large will follow speedily after this article.

106. The concentrated sulphuric acid is not decomposable by the greater number of metals, unless the temperature be elevated. When this is the case, sulphureous acid gas is disengaged, and oxides or metallic sulphates are formed according to the respective quantities of the acid and metals. If the sulphuric acid be diluted with water, it favours the decomposition of this last fluid by the metals; hydrogen is abundantly disengaged; the metals in proportion as they become oxidized unite with the acid, and form sulphates in greater abundance than under the preceding circumstances. The sulphureous acid acts in a different man-

ner

ner upon different metals. It dissolves some by producing a decomposition of water and disengaging hydrogen gas; frequently it is itself decomposed, yielding its oxygen to the metals, suffering its sulphur to precipitate, which unites to the sulphites, and causes them to pass to the state of sulphurated metallic sulphites. Upon some of the metals it has no action. As those metals which it dissolves by its own decomposition do not effervesce during their solution, it may be used with advantage in the analysis of alloys, carbonated metals, &c.

107. Concentrated nitric acid is frequently without any action whatever upon the metals because its density is too great. When it is diluted with a small quantity of water the action commences; nitrous gas is disengaged; and sometimes the decomposition is so strong and active, that azote gas is separated. There are cases, in which the water being decomposed at the same time on account of the large quantity of oxygen absorbed by the metal, affords ammonia by the union of its hydrogen with the azote of the acid, which is perceptible to the senses, particularly when lime is added. In this case the metal remains at the bottom of the vessel in the form of oxide. When nitrous gas only is slowly disengaged the oxidized metal remains in solution, and a metallic nitrate is formed, which crystallizes by cooling or by evaporation. Of all the acids, this burns the metals the most speedily and completely, sometimes

times even with flame, and in these instances the nitrates of least permanency are formed. Frequently also it acts upon oxides slightly oxidized, gives them a new portion of oxygen, and causes them to pass to the state of acidity when they are susceptible of it. The nitrous acid does not perceptibly differ from the nitric in its action upon the metals.

108. The phosphoric and phosphoreous acids, act but weakly upon the metals on account of the strong adherence of their principles, and their density. Nevertheless, when they are very strongly heated phosphorated hydrogen gas is disengaged towards the end. There are some among the most oxidable metals upon which the phosphoric acid acts the most effectually, and renders them capable of decomposing water more speedily than they could have done alone. In both cases phosphates are formed, and sometimes phosphites, which last salts are yet very little known. The metallic phosphates are usually weighty; sparingly soluble, or soluble merely in their proper acid, possess little or no taste, and are decomposable by many acids, as well as by ignited charcoal which changes them into metallic phosphorets. When the vitreous phosphoric acid is strongly heated with the metals, these substances by seizing a portion of its oxygen, form, at the same time, two combinations namely, metallic phosphates and phosphorets.

109. Carbonic

109. Carbonic acid, has a still more feeble action on metallic substances, than all the foregoing acids. It does not very perceptibly act, but upon zinc and iron, by keeping them dissolved in water. The water is slightly decomposed, a small quantity of hydrogen gas is formed, more distinguishable by its smell than by its disengagement, which never proceeds so far as to effervesce. The metallic carbonates are soluble in an excess of carbonic acid, and separate from the water when the acid is dissipated. Some of these are very abundantly found in nature. The carbonic acid, united with the earths, and in the state of carbonate, is sometimes capable of being decomposed by the metals, with the assistance of a red heat. Thus it is, that by heating the carbonate of lime with iron, and in fact, by adding the attraction of flint or sand for the lime, and of oxide of iron, with which this fusible earth tends to become vitrified, Citizen Clouet obtained steel, formed by the union of iron, with the carbon separated from the carbonic acid. A similar effect, will, no doubt, be hereafter observed, with regard to several other metals.

110. The muriatic acid does not dissolve the metals, unless they be capable of decomposing water, by the assistance of its disposing attraction; in that case, hydrogen gas is disengaged, and it is observable, that the gas is singularly and permanently fetid. The metals which never decompose water, are not attacked by this acid;

acid; but their oxides easily unite with it, particularly, because when too much oxidized to dissolve in the other acids, they, at first, yield to this acid, the excess of their oxygen. On this account it is, that the muriatic acid dissolves all the oxides, detaches them from the surface of vessels, and so frequently takes them from the other acids, particularly the nitric. The metallic muriates are either fixed or fusible, or volatile, and acidifiable.

111. Oxigenated muriatic acid oxides the metals, without producing commotion or effervescence, because the oxygen here acts only upon the combustible bodies. It easily acts upon those metals which the ordinary muriatic acid does not alter, particularly gold and platinum, and in this manner, it forms simple muriates. When it is added to the metallic salts, it almost constantly decomposes them, and precipitates the oxides super-oxigenated. When itself united with the oxides, it forms oxigenated muriates very different from the simple muriates, which have yet been little examined, though, we are already acquainted with some very remarkable compounds of this nature, as we shall observe in the following articles.

The oxigenated muriatic acid gas inflames and immediately burns most of the brittle metals thrown into it in powder. It acidifies those which are capable of that process.

112. The fluoric acid acts upon the metals nearly in the same manner as the muriatic, except

cept that it does not take the oxygen from their oxides like the latter.

The acid of borax has very little action upon these bodies, and cannot be united with their oxides, except by double attraction, or by decomposing other metallic solutions by solutions of the alkaline borates.

## SECTION II.

### *Concerning the Mutual Action of the Metals and the Salifiable Bases.*

113. THERE is no more real union between the earthy or alkaline bases and the metals, than exists on the part of the acids, but these bodies exercise an action with regard to the metals, which, though not so powerful as that of the acids, yet it possesses a peculiar degree of energy, and is of some importance to be considered. Thus, metals which are acidifiable, and those of which the oxides tend to combine with the earths and the alkalis, are easily and speedily oxidized when put into contact with these bases, together with a certain quantity of water. In that case, the water yields its oxygen to the metals, burns them, and they unite with the bases, which, in that case, act by disposing attraction.

114. Hence, it arises, that hydrogen gas is so frequently disengaged when the metals are treated

treated with alkaline solutions, particularly ammonia. We afterwards, observe the metals pass to the state of oxides, and frequently unite with the alkalis in such a manner as to form species of salts; in which, they perform the part of acids.

115. It is frequently observed, that alkaline solutions dissolve the metallic oxides, and form with them compounds more or less permanent; sometimes, these alkalis have the property of disoxidizing in part the oxides before dissolved or united with them. This is the reason why, when added to the metallic solutions, they change the colour of the precipitates, which, they afterwards re-dissolve, and may be separated by a new addition of acid.

116. Ammonia has much greater power to decompose the oxides, while itself is decomposed; and I have elsewhere observed, that this is one of the methods Citizen Berthollet used to analyze ammonia, by separating its hydrogen by the oxygen of the oxides, and setting its azote at liberty. Sometimes, as I have discovered, the great quantity of oxygen contained in certain oxides, and the facility it has of separating and uniting in part with the oxide of ammonia forms nitric acid, while the other portion of oxygen combined with the ammoniacal hydrogen forms water. This very remarkable case operated by the most decomposable oxides, is absolutely the inverse of that in which a very oxidable metal, by decomposing at the same  
4  
time



time the nitric acid and water, by absorbing all their oxygen, unites the combustible radicals, acid, and hydrogen in such a manner, that the product forms ammonia.

117. This property of reducing the oxides, so eminently perceptible in ammonia, and sensible also in pot-ash and soda, may serve hereafter to show the constituent principles of fixed alkalis, as it has served to develop those of the volatile alkali. But the experiments which have hitherto been attempted in this research, and the results they have afforded, have not yet satisfied chemists, because they have not been made with the accuracy they deserve to possess. Philosophers have been too ready in drawing inductions concerning the composition of the fixed alkalis.

118. The difixiding property is found in the very rapid alkaline earths, barites, strontian, and lime; when these earths are used to decompose the acid metallic salts, precipitates of metallic oxide are obtained, and assume a colour, which shows the commencing difixidation and approach towards the metallic state. To this action is owing the preparation of the calcareous oxide of copper, known by the name of verditer, of which we shall speak under the article Copper.

119. It is not improbable that it may be owing to a similar action, that an extreme solidity, and intimate adherence of particles, takes place in earths which are mixed with certain

tain metallic oxides in the formation of cements and durable mortars, impenetrable to water; which are obtained in many operations, and of which the theory has not yet employed the attention of chemists, though it is so highly and immediately of consequence in a multitude of important arts.

120. Though the facts and observations hitherto related, show that the earthy and alkaline bases have more attraction for the acids than the metallic oxides have, we must, nevertheless, observe in this place, that several of these bases have the property of uniting at the same time to the oxides and the acids without separating them, and form by this union triple salts, of which the number is much more considerable than has been supposed, as we shall see in the history of the various metals. Ammonia and alumine are of all the acidifiable bases, those which the most readily exhibit these species of sur-compounds yet little known.

121. Lastly, the alkaline bases and alkaline earths may also unite with the metallic oxides at the same time with the combustible bodies, to which they have a considerable attraction. In this manner the alkaline and metallic hydrosulphurets are formed, by dissolving the oxides in alkaline or earthy liquid sulphurets. We shall see that this effect is also produced by precipitating most of the metallic acid solutions by alkaline sulphurets, and that when various metallic sulphurets are treated by the alkalis, similar

similar combinations are also formed, among which the antimonial sulphurets hold, as we shall hereafter show, the first rank.

## SECTION XII.

### *Concerning the Mutual Action of the Metals and the Salts.*

122. THE salts which were formerly denominated middle, or neutral salts, have been, and still are, frequently used, as very powerful agents to occasion changes in the metals; in general their action takes place very weakly and slowly in a cold temperature; but heat increases this action in various degrees. We may easily understand, from the transposition of oxygen among the metals, that this action cannot take place but with salts of which the acids are decomposable, and that their result must be on the one part the oxidation of the metals, and on the other the union of the metallic oxides with the base of the salt. By enumerating the saline genera I shall show in what this action consists, and take notice of the action which the metallic oxides sometimes exert upon these compounds.

123. The sulphates, strongly heated with various metals, particularly those which decompose water, and even the sulphuric acid alone, by the assistance of heat, pass to the state of sulphurates,

fulphurets, which unite to the metallic oxides formed by this decomposition; antimony, zinc, iron, and tin particularly possess this property. The attraction of their oxides for the alkaline fulphurets, and the hidro-fulphuret is very effectual in the cause of this phenomenon. The oxides of these metals have no action on the sulphates. The sulphites act much less, though in a similar manner upon the metals.

124. The nitrates projected into ignited vessels, after first mixing them with fine filings of metal, take fire with more or less brilliancy with most of the metals, frequently with a small scintillation; but sometimes with a brilliant flame on account of the fixation of oxygen, which becomes more dense. In this manner, metallic oxides, at the maximum of oxidation are formed, which often unite with the bases of the nitrates. Those of the metals which are acidifiable, pass by this treatment to the state of acids, and combine into salts with the salifiable bases of the nitrates. Silver and gold alone resist this violent action of nitre, which is frequently used to prepare very perfect oxides with great speed. It may easily be conceived, that the metallic oxides undergo no change on the part of the nitrates when they are saturated with oxygen, the nitrites are nearly without energy on the metals, in comparison with the nitrates.

125. The muriates act but very weakly on the metals, and are themselves but slightly altered, nevertheless, the muriate of ammonia is easily

decomposed by all the metals, which are very soluble in the muriatic acid, as well as by the metallic oxides, which disengage the ammonia still more rapidly. The alkaline muriates appear also to be, at least, in part decomposable by most of these oxides; a circumstance, which may hereafter become of the greatest importance for the arts, and is already of high value with regard to lead and silver, as will be more amply shown in the article of these metals.

126. The super-oxygenated muriates are the most active salts with regard to the metals. We have elsewhere observed, that they burn with the rapidity and brilliancy of lightning, when struck upon the anvil, after having mixed them with two or three times their weight of super-oxygenated muriate of pot-ash. A similar mixture being heated, takes fire and detonates with a brilliancy of light and speed much superior to what is seen with the nitrates. By this process, very pure oxides are obtained; for the muriate of pot-ash may be very easily and completely separated by washing in water.

127. The phosphates and the phosphites undergo no alteration on the part of metals at any temperature whatever; and this consequence is in fact indicated by the common laws of attractions. The same observation is also applicable to the muriates, the borates, and the carbonates. Accordingly, these three last genera of salts can never be used to ascertain the properties of the metals.

128. Though

128. Though metallic oxides have in general less attraction for the acids, than the alkaline and earthy bases have, we, nevertheless, sometimes observe, that these oxides when heated with saline solutions are dissolved, become coloured, and combine so well with the salts, that the crystals afterwards obtained by evaporation and cooling, are manifestly charged with metal. Such, particularly, are the solutions of aluminous salts which appear to unite very easily with the metallic oxides, and afterwards to afford crystals, in which true triple salts are formed. These cases are much less rare than has hitherto been thought, and they will be more frequently observed in proportion as chemical researches shall be extended with regard to saline matters.

## ARTICLE II.

### *Concerning Arsenic and its Acid.*

#### SECTION I.

#### *Concerning Metallic Arsenic.*

##### *A. History.*

1. FROM the earliest period in which mankind worked the metallic ores, they must have ascertained the volatility, the odour, and the noxious effects of this substance. Nevertheless,

arsenic has remained unknown as a metal, and was not placed among the semi-metals or brittle metallic bodies till the expiration of about one-third part of the 18th century: notwithstanding, Paracelsus had announced, that it might be obtained white in the metallic form. Schroder, in 1649, mentioned a metal extracted from orpiment and arsenic; for we must here take notice, that the denomination of arsenic was long given to the oxide of arsenic. Lemery in 1675 also described a process, which is at present used with success in the mixture of fixed alkali and soap with this oxide, to obtain what is called the regulus. The ancients were acquainted with its oxide, its yellow and red sulphuret under the name of arsenic; Sandarach and Orpiment. Theophrastus placed them among the metallic stones. Mineralogists were, for a long time, content to range it among sulphureous matters, and consider it as a mineralizer of the metals. Brandt in 1733, and Macquer in 1746, showed that it is a true metal possessing properties highly characteristic, and different from those of every other metal. Monnet confirmed these observations by a number of facts in his dissertation, which obtained the prize of the academy of Berlin in 1773. Macquer made a capital discovery in 1748, by carefully examining the residue of the decomposition of nitre by white arsenic, or the oxide of arsenic, which afforded him his neutral arsenical salt: but Scheele extended

tended this discovery very much in 1775, by showing that this oxide is changed into a powerful acid by the action of the nitric acid ; and by this process, confirmed the ideas of Becher and Kunckel, who considered this oxide as a coagulated aqua-fortis. In the year 1777, Bergmann united in one dissertation, a great part of the properties of this metal in the metallic state, in the state of oxide, and in that of ore: The French or Pneumatic doctrine has classed and singularly enlightened all the facts relative to the properties of this metal.

#### B. *Physical Properties.*

2. ARSENIC has the form of small plates of a blackish grey, brilliant and metallic, whitish, and of a lively bright polish in its recent fractures, possessing the specific gravity as stated by Bergmann, of 8,310, and by Guyton 5,763. It is extremely brittle, the smallest effort breaks it into minute fragments; it may be easily pulverized by percussion, and reduced into a subtle powder capable of passing through the finest silken sieves. It possesses the last rank in the order of hardness according to Citizen Guyton. Bergmann, however, affirms that it is harder than copper; it is frequently marked with rainbow colours at its surface; its fusibility is not known, because it sublimes before it melts; it is the most volatile of all the metals; it  
cryf-



crystallizes when slowly sublimed in a regular tetrahedron, and sometimes in the form of an octahedron. The first form is that of its integumentary particles. Neither its taste nor smell are very perceptible when cold: nevertheless, it leaves on the fingers a slight metallic taste, and in the mouth, a sharp peculiar taste, which is very disagreeable. When it is heated, it possesses the form of vapour, and exhibits a very strong fetid smell of garlic, which may be considered as the characteristic token of its presence. Neither its dilatibility by caloric, nor its conducting power of that substance, or of electricity, have been estimated.

### *C. Natural History.*

3. ARSENIC frequently exists native in ores; it has, almost always the form of blackish masses of little brilliancy, very heavy, exhibiting no metallic splendor but in their fracture, which, frequently presents rainbow colours. Its fracture is almost always scaly and conchoidal. This metal was long confounded with the ores of cobalt, and denominated testaceous cobalt. It varies in its colour from deep grey to black: in its lamellated form, scaly, pulverulent; and its state of deposition of stalactites, of incrustation, of crystals; it is often found with the ores of cobalt, of bismuth, of nickel, of silver, in Saxony, Hungary, Bohemia, and at the mines of St. Mary.

**Mary.** It may be unequivocally ascertained by throwing a few small fragments upon ignited coal; a white fume instantly rises with the smell of garlic.

4. Nature frequently presents arsenic combined with other metals. We are not yet well acquainted with ores of this kind, except the mispickel, or arsenical pyrites, which is a true alloy of iron and arsenic with sulphur. Iron composes from one-half to two-thirds of its mass according to Bergmann, though it is not attracted by the magnet. When this native alloy is heated, the arsenic sublimes, and the iron remains partly reduced and attractable by the magnet. This alloy crystallizes in cubes, of which the angles are often truncated.

5. A third, very frequent state of arsenic in nature, is that of its combination with sulphur. It presents two principal varieties, the one yellow, known under the name of orpiment, the other red, named Realgar, which are sometimes transparent, and often opaque. The yellow affects the lamellated form, and the red the prismatic. We are not yet well acquainted with the difference of these two compounds in which the arsenic appears to be but little oxidized. They frequently assume a pyramidal or tetrahedral form considerably perfect; sometimes in the mass of calcined ore of arsenic we observe only pyramids of sulphuret of arsenic, composed of filaments parallel to the sides; so that one of the hollow triangular pyramids being frequently filled with small  
pyra-

pyramids, produces a tetrahedron with the other pyramids progressively decreasing, and the eight tetrahedrons suitably disposed produce the octahedron. Here, as Bergmann observes, from whom this description is taken, we see a crystallization in the dry way absolutely similar to that which is afforded in the humid way by muriate of soda, the muriate of pot-ash, and perhaps, all the other salts. We see, that this skilful chemist noticed the laws of diminution to which Citizen Haüy has paid such successful attention. The yellow and red sulphurets of arsenic vary in their form, and the shade of their colour. They are found in numerous places in the vicinity of Volcanos; particularly at Vesuvius and Quito. Sometimes, they are alloyed with iron, in which case, their colour is pale, and even becomes white. These sulphurets are totally sublimable.

6. Arsenic is sometimes found in the earth in the state of pure white oxide, or arsenious acid, as we shall see hereafter: but this is scarce, and always in small quantity. In the territories already mentioned, it is formed either in powder or in efflorescence, or in white masses deposited in strata, sometimes transparent, frequently mixed with yellow or red sulphuret of arsenic. It is distinguished by its garlic vapour, when thrown in the fire, as well as by its acrid metallic taste, and its solubility in water.

7. We are, not yet acquainted with the nature of the oxide of arsenic united to acids.

On

On the contrary, we know that this metal in the state of acid, is frequently itself the mineralizer of various other metals.

*D. Docimaestic and Metallurgic Operations.*

8. NOTHING can be more simple and easy than the assay of the ores of this metal, since it consists merely in ascertaining its presence by the white fume and the odour of garlic which they present when thrown on ignited coal. A true assay of these ores for metallic works is never made.

9. In scientific chemistry, if it be desired to ascertain the quantity of metal contained in a native oxide of arsenic, or which is the same thing, to obtain metallic arsenic from its oxide, this substance is mixed with three times its weight of black flux; the mixture is put into a crucible and covered with another reversed and luted in such a manner as to prevent the access of air. The lower crucible is heated by degrees to ignition, at the same time that the upper is defended from the heat, and the flame by a perforated copper-plate. When the apparatus is cool, the upper crucible is found to contain a crust of metallic arsenic, brilliant and crystallized, easy to be detached, of which the weight may be compared with that of the ore, or rather the oxide employed.

Bergmann, in his Dissertation on the Humid Analysis, directs us to assay native arsenic by dissolving

dissolving it in four parts of nitro-muriatic acid, concentrating the solution by evaporation, and precipitating by water the muriate of arsenic. The filtered liquor contains the other metals which may exist in the ore. If it contain silver, this may be thrown down in the form of insoluble muriate. Iron is frequently found in the solution precipitated by water.

11. The sulphuret of arsenic must be treated with the muriatic acid, by adding a small quantity of nitric acid to separate the sulphur; this last is collected, washed, and weighed; the oxide of arsenic is also capable of being precipitated by water; arsenic may also be obtained in the metallic state by immersing zinc in the muriatic solution, after having added alcohol. If it contain iron it remains suspended. By this assay it is determined that the different proportions of sulphur occasion the variations of colour in the sulphurets of arsenic.

12. With regard to the native oxide of this metal, its assay must also be made by the muriatic acid, which dissolves it. Bergmann very properly recommends that the nitric acid should be used with great caution in these assays, because it easily converts the arsenic into the acid state, which is no longer precipitable by water; he even remarks, that a small portion is constantly formed, which unites with the earths and metallic oxides existing in the ores of arsenic, and of which it is necessary to take account in an accurate doctimastic analysis.

13. The ores of arsenic are not treated in the large way for the purpose of obtaining the metal; its two products are obtained in the treatment of several other ores, particularly those of cobalt; and both are extremely dangerous in their uses. In Saxony and Bohemia the oxide of arsenic, or a true arsenious acid is obtained during the roasting of the ore of cobalt. These products sublime and fix themselves in long horizontal chimnies proceeding from the furnaces. This article is sold under the name of white arsenic.

14. Loaves, or masses of metallic arsenic, of a blackish-grey colour, are also prepared in the large way, consisting of plates irregularly arranged, so as to leave a great number of pores and cavities. These, probably, are obtained in the large way by treating other arsenical ores; and they are sold under the dangerous and deceitful name of testaceous cobalt, or powder for killing flies. Bergmann, who also rejects this erroneous expression, is deceived when he affirms that this substance does not kill flies unless it be in the state of oxide. The experiments of our peasants, who strew this powder in plates containing water, which are placed even on dining tables, and soon become filled with dead flies, proves that the metal itself, though insoluble, is extremely poisonous.

*E. Concerning the Oxidability of Arsenic by the Air.*

15. ARSENIC, in the brilliant metallic state, and recently prepared, soon changes, even in the cold, by the contact of the air. Its surface is oxidized at first of a dull colour, and at last becomes black, at the same time that it loses its hardness, and becomes extremely friable, and even pulverulent.

16. When it is heated with the contact of air, and particularly when its powder is thrown on red-hot coals, it burns with a very perceptible blue flame; it emits fumes having a strong smell of rotten garlic, and it sublimes in a white, acrid, soluble mass, which has been denominated oxide of arsenic, but which I shall describe under the name of the arsenious acid. Citizen Guyton places it in the seventh rank of oxidability after antimony. I consider it as one of the most combustible among metallic substances.

*F. Union with Combustible Matters.*

17. No union is known to subsist between arsenic, azote, carbon, and the diamond; it is known to be soluble in hydrogen gas, to which it gives a fetid smell, and poisonous property. Its combinations with phosphorus, sulphur, and the metals have been determined.

18. When

18. When equal parts of phosphorus and arsenic are distilled with careful management of the fire, a brilliant blackish sublimate is obtained which burns on ignited coals with a mixed odour of these two combustible bodies. A black residue is left abounding with phosphorus, which must be kept under water, and is the phosphoret of arsenic. This combination may also be made under water at a boiling heat in a glass vessel; the phosphorus unites with the arsenic by fusion. The characters of this phosphoret of arsenic are not yet known.

19. Arsenic is easily combined with sulphur by fusion and by sublimation. It then forms a yellow or red compound. This last colour shows that the metal preserves its metallic nature. For when this compound is oxidized by the action of acids it passes to yellow. It is a perfect imitation of the native red sulphuret of arsenic, or realgar, which has sometimes been named on account of its colour, the ruby of arsenic. The alkaline sulphurets also dissolve, arsenic with facility, which adheres to them but weakly, and is easily separated by all the other metals. The hydro-sulphuret of arsenic is not yet known.

20. Arsenic unites very easily with most of the metals. As it is the first metal which is examined individually in this work we cannot treat of its alloys, but in a general manner; because we shall return to them under each of the twenty following metals. By uniting with  
the



*H. Action of Arsenic upon the Acids, and of the Acids upon Arsenic.*

25. IN general, those acids only which are easily decomposed, appear capable of acting upon arsenic and supplying it with oxygen. Few of them can hold it in solution, on account of the acid nature which it assumes by its oxidation; it therefore, always falls down in the form of a white powder from its solutions. Most of the acids, by a considerable action upon arsenic, convert it into arsenic acid, or at least into arsenious acid; and it has then much more tendency to unite with the alkalis, than to combine with the acids; accordingly, it separates from the latter, or at least it does not unite with them; when, therefore, we obtain solutions of arsenic, they are always made with excess of acid, little charged with oxide; they have little permanency, they become turbid by evaporation, or by the simple addition of water.

26. The concentrated sulphuric acid does not attack arsenic in the cold; when it is boiled upon this metal in powder or in small fragments, it produces an effervescence; sulphureous acid gas is disengaged: the arsenic becomes oxidized and remains at the bottom of the vessel in a white powder, which retains but little sulphuric acid; washing with water carries off most of this last, and leaves the arsenic with little diminution. There is not, truly, a sulphate

phate of arsenic. No crystals are obtained from this solution; by evaporation, the arsenious acids falls down, and the sulphuric acid remains suspended. No action takes place between the sulphureous acid, and the arsenic acid.

27. Concentrated nitric acid attacks arsenic in powder with much vivacity, or rather this metal rapidly decomposes the nitric acid; nitrous gas is disengaged, and towards the end azote. The arsenic is changed into a white powder much heavier than the metal was before. It is first the arsenious acid which may pass to the state of arsenic acid, if a new quantity of nitric acid be made to act upon it; sometimes, even when a large quantity of this acid has been taken, and its action is assisted by heat, the metal speedily becomes arsenic acid, and no oxide remains in the supernatant acid, so that there is no nitrate of arsenic afforded. Chemists who have spoken of such a nitrate, obtained a solution of arsenic acid, and consequently were induced to assert, that the alkalis do not precipitate this metal. The nitrous acid produces this effect of acidification upon arsenic still more speedily.

28. There is no perceptible action between the phosphoreous and phosphoric acids and arsenic; by means of an elevated temperature continued for some time, a small quantity of arsenic is oxidized, but weakly and almost in an insensible manner: the same observation applies to the carbonic acid.

29. The muriatic acid has no action in the cold upon arsenic; when it is made to boil, it perceptibly dissolves it, and gives out a fetid gas, which appears to be arseniated hydrogen. The muriatic acid, therefore, renders water decomposable by arsenic. Bergmann has remarked, that this acid is the best solvent of the metal here spoken of, and accordingly, he has recommended it for the assays of its ores. A small quantity of nitric acid being added, renders the solution more speedy. This solution heated and concentrated in closed vessels, sublimes totally in the form of a thick fluid, which was denominated butter of arsenic. It is decomposed by water alone, which separates the arsenious acid. It is, therefore, only a transient muriate of arsenic, which cannot be compared to a true metallic salt.

30. The oxygenated muriatic acid acts upon arsenic with much greater force and rapidity. This metal, when thrown in the state of powder into oxygenated muriatic acid gas, becomes instantaneously inflamed, and burns with a white and very bright flame; it afterwards exists in the state of arsenious acid. If we add to it liquid oxygenated muriatic acid, it speedily passes into the state of arsenical acid, whilst the former is restored to the state of ordinary muriatic acid. The same acidification is effected by pouring oxygenated muriatic acid into the solution of arsenic by the ordinary muriatic acid.

31. The

31. The fluoric and the boracic acids exert no action at all upon arsenic. We shall see hereafter what are its habitudes with respect to the metallic acids, and even with respect to its own or the arsenic acid.

*I. Action of the Bases and Salts upon Arsenic.*

32. No earthy or alkaline base exerts any real action upon arsenic, nor effects any oxygenation of it by water, at least unless we boil this metal for a long time, in the state of fine powder, in a large quantity of alkaline solution. Ammonia is equally inert with respect to this metal.

33. The sulphates are not decomposed by arsenic; the heat which it would be necessary to employ in order to favour this decomposition, is superior to that which volatilizes this metal; still less can it suffer any alteration by the action of the sulphites.

34. The nitrates burn arsenic and detonate with it. They convert it into arsenical acid by the great quantity of oxygen which they impart to it; and this acid, combining with the bases of the nitrates, forms arseniates which remain at the bottom of the vessels in which this operation is carried on.

35. No action, no combination, no decomposition is known between arsenic and the muriates. The super-oxygenated muriates, on the contrary, exert a considerable action upon this

metal. When three parts of super-oxigenated muriate of pot-ash have been mixed with one part of arsenic in fine powder, (a mixture which must be made with great caution, and without applying much friction or compression to the substances, lest spontaneous inflammation and detonation should take place), if we strike small portions, placed upon an anvil or folded in paper, with a hammer, a considerable fulmination attended with flame is produced. If we approach a body in the state of combustion to the same mixture, it kindles and burns with excessive rapidity. Poured upon concentrated sulphuric acid, it emits a flame, at the instant of contact, which raises itself in the air, flashes like lightning, and is so brilliant that it dazzles the eyes.

36. No action is known to be exerted upon arsenic by the phosphates, which themselves undergo no alteration. The phosphites when heated with this metal, yield a small quantity of phosphuret of arsenic.

37. The fluates, borates, and carbonates exert no action at all upon it; when we heat it with borax by means of the blow-pipe, it becomes volatile, burns, and does not remain fixed in the vitreous globule formed by this salt.

#### K. *Uses of Arsenic.*

38. **ARSENIC**, in the metallic form, and such as it has been described in this paragraph, is  
but

but little employed, except in chemical laboratories, where various experiments, researches, and demonstrations are carried on.

39. As it is sometimes employed for killing flies, great caution should be used in applying it to this purpose; for this substance, which is sold under the name of testaceous cobalt, or fly-powder, is very dangerous to all animals, though some chemists are of the contrary opinion. The antidotes against its poison shall be enumerated hereafter.

40. In some manufactories it is alloyed with various metals, in order to whiten and harden them; the white copper is frequently an alloy of this kind. We shall speak of this subject in the history of the other metallic substances; it is only of importance to observe in this place, that, though such alloys may be of utility in some cases, they ought never to be employed in utensils for the preparation of aliment, drinks, or medicines,



SECTION

## SECTION II.

*Of the Arsenious and Arsenical Acids.*

## SPECIES I.

*The Arsenious Acid.*

1. I WAS the first who applied, some years ago, the name of arsenious acid (*acide arsenieux*) to the substance which is known in commerce by the name of *white arsenic*, (*arsenic blanc*), and which has been termed oxide of arsenic in the Methodical Chemical Nomenclature. The manifestly, though slightly, acid properties of this pretended oxide, which had already been ranked amongst the acidified substances by some of the ancient chemists, induced me to do so, as well as the advantage of comparing its properties in the history of arsenic and the arsenical acid, with those of the phosphoreous and sulphureous acids, in the history of phosphorus, sulphur, and the phosphoric and sulphuric acids.

2. This acid is found frequently, if not abundantly, in nature; it is known, and I have myself indicated it amongst the arsenical ores, by the name of *native oxide of arsenic*: it is obtained in the large way, and sublimed in working various ores, especially those of cobalt. It is prepared by heating and burning arsenic in subliming apparatuses, to which the air has access;

cess; it is also this substance which is formed when the arsenic is supposed to be simply oxidized by the sulphuric, nitric, muriatic, and oxygenated muriatic acids; finally, it is this weak acid which results from all the circumstances in which arsenic is oxidized to whiteness; so that there is no real oxide of this metal except that which is black.

3. The acid characteristics of this burned substance are the acrid taste, its caustic and *poisonous* property, that of changing feeble blue colours into red, of precipitating the alkaline and earthy sulphurets, of dissolving in water, of uniting with the alkalis and earths; and, as a weak *poisonous* acid, it is volatile, less soluble than the arsenical acid; its salts are much more decomposable than those of the latter: but its differences and variations will be better understood by studying its real properties.

4. The arsenious acid is very volatile: when we heat it slowly in close vessels, it sublimes in regular tetrahedral crystals, which are transparent like glass. Frequently the tetrahedrons have their angles truncated. It forms dense, semi-transparent layers in the chimneys where the ores of cobalt are worked, appearing in the form of a powder or of small needles: this was formerly termed *flowers of arsenic*. This acid is so extremely acrid and caustic, that it corrodes the organs of animals; it is the most deleterious of all known poisons. Its specific weight is less than that of arsenic; it weighs between 4,000 and



and 5,000: the oxygen with which it is combined keeps therefore the molecules of the arsenic more separate from each other than in their metallic state; it reddens the most sensible and alterable blue vegetable colours, though it turns the syrup of violets green; when exposed to the air, it becomes opaque and covered with a slight efflorescence.

5. The arsenious acid is very easily alterable by hydrogen, carbon, phosphorus, and sulphur; the two first deprive it of its oxygen in a red heat, and cause it to return to the state of arsenic; the one forming water, and the other carbonic acid. The phosphorus and sulphur become in part acid, and in part constitute with the arsenic, which they restore to the metallic state, arsenical phosphoret or sulphuret. It is on this account that Margraff and Pelletier, who have particularly occupied themselves with the metallic phosphorets, have said that we might form them with white arsenic, or the arsenious acid.

6. Water dissolves the arsenious acid pretty easily; it requires no more than twenty-four parts at ten degrees to dissolve one part of the acid; hot water dissolves more of it than cold, for fifteen parts of boiling water are sufficient to dissolve one part of this acid; the solution also deposits crystals.

By refrigeration, but much better by evaporation, regular tetrahedrons are obtained from it. This solution is very acrid, reddens the  
blue

blue colours, unites with the earthy bases, decomposes the alkaline sulphurets, and yields with them a yellow precipitate, in which the arsenic approaches the metallic state. There are even some metals which act upon this solution, and which tend to decompose the acid, so as to form a blackish precipitate, which approximates to the state of arsenic.

7. Between this and the other acids no action takes place, except one of a very different nature from that which they exert upon the metals; boiling sulphuric acid dissolves a small quantity of arsenious acid, which is precipitated by refrigeration; nitric acid, without dissolving it, becomes decomposed with the aid of heat, and converts the arsenious into arsenical acid. The phosphoric and carbonic acids do not act upon the arsenious acid; nevertheless, this acid enters into a vitreous combination with the phosphoric and boracic acids. Muriatic acid dissolves it with the aid of heat, and forms a volatile combination which water precipitates; the oxygenated muriatic acid converts it into arsenical acid.

8. The arsenious acid combines with the earthy and alkaline bases; the first form with it arseniates that have little solubility; hence its solution is precipitated by those of barites, strontian, and lime. The fixed alkalis form dense arseniates, which do not crystallize, which are decomposable by fire, of which caloric volatilizes the arsenious acid, and from which all the  
the

the acids precipitate it in a pulverulent form. These saline combinations were formerly termed *livers of arsenic*, as they were compared with the compounds of sulphur and the alkalis. The earthy and alkaline arsenites have as yet been but little examined. What is known of them is barely sufficient to distinguish them from the arseniates, or the compounds resulting from the combination of the arsenical acid with the same bases.

9. There exists still another species of combination between the arsenious acid and the earths; namely, those which are formed in employing it for the purpose of vitrification. Though a portion of this volatile acid is sublimed previous to the fusion of the glass, another part remains fixed in the vitrified substance, which gives it transparency, an homogeneous density, and a considerable weight: it even appears that there exists in the arsenicated glasses a kind of triple salt; for the alkalis and the sand enter into intimate combination at the moment of fusion, and remain intimately united.

10. If we except the nitrates and oxygenated muriates, the other salts have but little action upon the arsenious acid; it exerts none upon the sulphates, the muriates, and the fluates; it is only with the assistance of heat that it decomposes the carbonates, from which it expels the acid with effervescence, in order to unite with their bases; it is not without difficulty that it  
expels

expels and precipitates the acid of the borates. It is, however, to be remarked, that on heating the muriate of soda with the arsenious acid, a portion of its muriatic acid is disengaged.

11. But the nitrates and the super-oxygenated muriate of pot-ash act in a very remarkable manner upon the arsenious acid; it decomposes the first in such a manner as to disengage from them the nitrous acid, or nitrous vapour, which it is very difficult to coerce, as Kunckel had long ago observed; it absorbs a part of its oxygen; it passes into the state of arsenical acid, and it leaves arseniates in the distilling vessels. The same phenomenon takes place when we detonate the arsenious acid with the nitrates; for it is still sufficiently combustible to effect a detonation, without sparks indeed, but with commotion and effervescence; and real arseniates remain at the bottom of the crucibles. It was in this manner that chemists formerly prepared *fixed arsenic*, which is the acidulous arseniate of pot-ash, concerning which we shall treat hereafter. The super-oxygenated muriate of pot-ash also, by completely burning the arsenious acid, effects its conversion into arsenical acid, which is able, with the aid of fire, to decompose the remaining muriate of pot-ash.

12. The arsenious acid is applied, under the name of arsenic, or white arsenic, to a variety of uses in the arts; it is employed in a great number of cases, in which it is reduced and acts

as

as a metal, as shall be shown hereafter. Some physicians have ventured to employ this terrible acid as a medicine, and assure us that they have found it very efficacious; but it is always much more to be dreaded as a poison, than esteemed as a remedy. Waters charged with fulphurated hydrogen gas are amongst the best counter-poisons that can be administered against the effects of this dangerous substance. The alkaline fulphurets dissolved in water, prove very successful, immediately after a person has been poisoned with arsenic; bland insipid liquids, milk, fat, oils, are sometimes rather dangerous than salutary, as they envelop, and in some measure, fix the arsenious acid upon the stomach.

## SPECIES II.

### *The Arsenical Acid.*

1. THOUGH Macquer first ascertained the difference between the combinations of this acid and those of the preceding, it was not till the year 1775 that Scheele discovered the artificial formation of the arsenical acid, by distilling nitric acid upon a muriatic solution of arsenious acid, which he believed to exist in the oxide of arsenic. This able Swede was the first who described the remarkable properties of this acid. He also prepared it by treating the arsenious

senious acid with the oxygenated muriatic acid: Bergmann added several useful facts to this discovery. The pneumatic theory proved to the French chemists, that, during this conversion into a more powerful acid, the arsenious acid abstracted oxygen from the nitre or the nitric acid, and from the oxygenated muriatic acid. Pelletier, on examining various properties of this acid, found that by decomposing the nitrate of ammonia by means of the arsenious acid, and afterwards applying heat till the ammonia was disengaged, the arsenical acid was left alone and pure at the bottom of the distilling vessel.

2. The arsenical acid is prepared, either by distilling six parts of concentrated nitric acid from the arsenious acid, or by heating concentrated nitric acid upon twice its weight of a muriatic solution of arsenious acid, or by dissolving the latter in liquid oxygenated muriatic acid, or by receiving this, in the form of gas, into a solution of arsenious acid. In all these processes we obtain an acid which does not crystallize, which has a dreadfully acrid and caustic metallic taste, which is fixed in the fire, and can sooner be fused into glass than volatilized; which reddens even the syrups of violets, and which has much stronger attractions than the arsenious acid. Its specific weight is 3, 391.

3. When we heat this acid in a retort or a crucible, it melts quietly; it attacks the glass of the retort or the earth of the crucible; it remains transparent and pure at a very high temperature;

perature; it yields a small quantity of oxygen gas, and returns in part to the state of arsenious acid: bright light also favours this disacidification, which particularly takes place when we strongly heat this powerful and caustic acid in a transparent vessel. When the arsenical acid contains a small quantity of arsenious acid, we separate the latter from it by the action of fire, as is done with the sulphureous and nitrous acids, when united with the sulphuric and nitric acids.

4. Exposed to the air, it quickly attracts humidity; it is entirely and completely deliquescent; it absorbs also two thirds of its weight of atmospherical water, a quantity sufficient to hold it in solution.

5. When the arsenical acid is heated with combustible substances, of whatever kind they may be, they decompose it, abstract from it its oxygen, cause it to return into the state of arsenious acid, and from thence into that of arsenic. Also hydrogen gas, received into a solution of this acid, possesses this property in a sufficient degree to precipitate its solution; still more decidedly must this effect be produced by sulphurated hydrogen gas, by water charged with it, and by the alkaline sulphurets. Carbon, phosphorus, sulphur and most of the metals produce the same effect, either by the aid of caloric, or even by simple contact, as is observed with several of the last mentioned substances: heated with carbon in a retort, the arsenical acid inflames the carbon, and passes into

into the metallic state. Sulphur heated with the arsenical acid, puffs up, is converted partly into sulphureous acid gas, and partly sublimes into red sulphuret of arsenic; heated with phosphorus, it converts a portion of it into phosphoric acid; and having become arsenic, it unites with another portion of the phosphorus, with which it forms phosphoret of arsenic, which sublimes. Arsenic, or the metal itself, heated with arsenical acid, deprives it of a portion of its oxygen; and the two substances, united reciprocally in an equilibrium of oxidation, pass together into the common and uniform state of arsenious acid.

6. The arsenical acid is much more soluble in water than the arsenious acid; it requires not more than three or four parts water, in order to become well dissolved and fluid; it cannot by any means be crystallized, and when evaporated, it assumes a thick consistence like that of honey. It does not act in the cold upon the oxides, which decompose it at a high temperature; it combines with various metallic oxides, as shall be shown more at length under the subsequent articles.

7. None of the acids exert any action upon the arsenical acid: though some of them dissolve it by means of their water and their liquid state, they do not induce any alteration in it. The boracic and phosphoric acids, with the aid of fire, enter with it into the state of vitrification, but without mutually changing the nature of each other. The phosphoreous acid,  
when



when heated for some time upon arsenical acid, saturates itself with oxygen, and becomes phosphoric acid.

8. The arsenical acid combines with all the earthy and alkaline bases, forming salts very different from those afforded by the arsenious acid. All the earthy and alkaline arseniates are decomposable by carbon, which, with the aid of heat, separates arsenic from them. The arseniate of barites is insoluble, uncrySTALLIZABLE, soluble in an excess of its acid, decomposable by sulphuric acid, which precipitates sulphate of barites from it. The arseniate of strontian is not known, but it is certainly analogous to that of barites.

9. Poured into lime-water, the arsenious acid forms in it a precipitate of lime soluble in an excess of its base, or an excess of its acid, though it be insoluble alone. The acidulous arseniate of lime yields, by evaporation, small crystals that are decomposable by the sulphuric acid. The same salt is formed with the carbonate of lime, introduced into the solution of arsenical acid. This acid does not decompose the nitrate and muriate of lime, but the saturated alkaline arseniates decompose them by a double attraction, and precipitate from them insoluble calcareous arseniate.

10. When we saturate the arsenical acid with magnesia, a thick substance is formed as it approaches the point of saturation. This magnesian arseniate is soluble in an excess of acid;  
by

by evaporation it assumes the form of a jelly, without crystallizing. The arsenical acid decomposes neither the sulphate, nor the nitrate, nor the muriate of magnesia; this decomposition is effected only by the saturated alkaline arseniates.

11. The arsenical acid saturated with potash, does not crystallize; evaporated to dryness, the arseniate of pot-ash attracts the humidity of the atmosphere; it turns the syrup of violets green; but does not alter the tincture of turnsole. This salt melts into a white glass; the contact of the flux and alumine of the crucible over a strong fire, causes it to pass into the acidulous state, of which I shall speak immediately. It puffs up violently and yields well-sublimed arsenic, when heated with carbon to redness in close vessels; it is decomposed by the sulphuric acid, which disengages the arsenical acid from it: this decomposition is not perceptible by the humid way, because the arsenical acid is not separated in the solid form, but remains in solution; but we find sulphate of pot-ash and the last-mentioned acid in the mother water, on evaporating the liquid. The arseniate of pot-ash decomposes the salts that have lime and magnesia for their bases, and forms precipitates of calcareous or magnesian arseniate, in their solutions.

12. If we add arsenical acid to the preceding salt, till it no longer alters the colour of violets, it still reddens that of turnsole; it yields very regular and transparent crystals in quadrangular  
 VOL. IV. I prisms,

prisms, terminated by two tetrahedral pyramids, the angles of which answer to those of the prisms: this is the *neutral arsenical salt* of Macquer. It is this salt which is obtained by decomposing the nitrate of potash with the arsenious acid in equal parts; in order to distinguish it from the preceding, it ought to be termed the acidulous arseniate of potash; it differs from the other not only by its crystallizability, but also by the circumstances, that it does not decompose the calcareous and magnesian salts, as that does; that it reddens the blue colours, and that it is capable of absorbing a new portion of potash, so as to pass into the neutral state. These two salts, like all the following, are decomposed by barites, strontian, lime and magnesia.

13. The arsenical acid, combined with soda to saturation, forms a salt which crystallizes like the preceding: Scheele already compared this salt with the acidulous arseniate of potash. Pelletier says, that the arseniate of soda crystallizes in hexahedral prisms, terminated by planes perpendicular to their axes. For the rest, the habitudes of this salt are the same as those of the arseniate of potash, in its decomposition by carbon, the acids, and the earths: Scheele remarks, that if we add arsenical acid to it, instead of crystallizing, it becomes deliquescent: this is a property diametrically opposite to that which obtains in the arseniate of potash.

14. Com-

14. Combined with ammonia, the arsenical acid forms a salt which yields rhomboidal masses analogous to the crystals of nitrate of soda. The arseniate of ammonia, which is also the product of the nitrate of ammonia decomposed by the arsenious acid, is decomposable in two different ways by the action of caloric. If we heat it gently, the ammonia is disengaged, and the arsenical acid is left in a pure state. If we expose it to a strong and brisk fire, part of the volatile alkali and of the acid mutually decompose each other; water is formed, azote gas is disengaged, and arsenic is sublimed of a brilliant appearance. Barites, strontian, lime, the two alkalis, decompose the arseniate of ammonia, and seize upon its acid. Magnesia decomposes it in part, and forms a triple salt with a portion of this salt.

15. The arsenical acid saturated with alumine, forms a thick solution, which, evaporated to dryness, yields a salt insoluble in water, and decomposable by the sulphuric, nitric, and muriatic acids, as well as by all the earthy and alkaline bases. The arsenical acid also precipitates none of the aluminous salts formed with these acids. The arsenical acid, by its fusion, easily dissolves the alumine of the crucibles; it also attacks flint; but it effects no alteration in these substances by the humid way. The combination of this acid with zirconia is not known.

I 2

16. With

16. With the aid of a strong heat, the arsenical acid decomposes the alkaline and earthy sulphates, even the sulphate of barites; the sulphuric acid is disengaged in the state of vapour, and arseniates remain in the retort; it acts in the same manner upon the nitrates, from which it disengages the pure acid; at a high temperature, it also decomposes the muriates, disengaging the muriatic acid in the form of gas; it unites with their bases, which it saturates: this cannot be done by the arsenious acid, for it is too volatile to produce such an effect. It acts in the same manner upon the fluates, and with much greater facility upon the carbonates, with which, by heat, it produces a lively effervescence. It exerts no action upon the phosphates, and it precipitates the boracic acid from hot solutions of the borates.

17. The proportions of the principles of the arsenical acid are hitherto unknown; its respective quantities of arsenic and oxygen have not yet been ascertained, no more than those which compose the arsenious acid. However, there is every reason to believe, that the first contains oxygen in the proportion of at least a sixth part of its weight, whilst the arsenious acid perhaps does not contain more than a twelfth.

18. The arsenical acid is not yet applied to any use in the arts, at least, not in a direct manner: we shall see hereafter that it forms an ingredient in certain compositions for dyeing; it is also one of the mineralizing acids which  
nature

nature has combined with some metallic oxides. It is prepared in chemistry for the purposes of experiments and demonstrations belonging to this science. When its nature shall have been better studied, it will, very probably become of great utility in manufactures.

### ARTICLE III.

#### *Concerning Tungsten and its Acid.*

##### SECTION I.

#### *Concerning the Metal Tungsten.*

##### *A. History.*

1. **THOUGH** Scheele was the first chemist who discovered and announced the metallic nature of tungsten, (a name at first given to a white, very transparent mineral, which contains the acidified metal united to lime, and which name was afterwards transferred to the metal itself :) though Bergmann in the same year 1781, confirmed the discovery of Scheele ; yet, we must refer our first knowledge of its metallic properties to Messrs. D'Elhuyar, Spanish chemists, who having discovered the same metal in the mineral called wolfram, obtained it sufficiently reduced to exhibit several of its characters. Since their time, Mr. Angulo has repeated their experiments,

ments, and obtained the same results at Dijon in the laboratory of the academy.

### *B. Physical Properties.*

2. THE metal hitherto obtained, or tungsten, had the form of a button composed of very brittle small globules of the grey colour of steel; its specific gravity, 17,6; so that it has a density intermediate between gold and mercury. It is so difficult of fusion, that it even exceeds manganese in this intractability, and consequently it is, with platina, one of the most infusible of metals. Citizen Guyton has given it the fifth rank for its hardness; he places it with zinc as to brittleness, and consequently, according to his statement it is less brittle than bismuth.

### *C. Natural History.*

3. It has not yet been found native, nor alloyed, nor combined with combustibles, nor united with acids; it has only been found in the acid state combined with lime, with iron and manganese, and with lead.

4. The first of these combinations is the tungsten of the Swedes; the second is named wolfram; and the third, the yellow ore of lead. It is more natural to speak at some length respecting the history of the tungstic acid itself, which is much more advanced than that of the metal

metal which composes its radical ; and also its combination with iron and lead.

*D. Assay and Metallurgy of the Ores of Tungsten.*

5. THE assay of these ores is made less with a view to separate the metal than to prove the presence of its acid, because the intention of the operator is rather to obtain the acid than the metal. It is usual, therefore, to treat the metal supposed to contain native tungstate of lime with the nitric and muriatic acid ; these acids, when heated to a certain degree upon this substance, convert it to a yellow colour, if it contain the tungstic acid ; and it is to this simple operation, which in truth, is nothing more than its mineralogical character that the assay of this ore is confined,

6. No metallurgic works have yet been carried on with the ores of tungsten. Though some of them have been found already in sufficient abundance, no process has as yet been undertaken, neither in the art of extracting the metal in the large way, which would prove extremely difficult on account of its insolubility, nor on that of preparing or extracting any useful matter from it.

7. In order to obtain the metal in the chemical laboratories, which has not yet been performed, but on a very small scale, the tungstic acid is separated from the ores by the process described in the next paragraph, then  
mixed



mixed with charcoal, and urged by heat in a charcoal crucible. A very strong heat is required for its reduction and fusion; accordingly, this has been effected only in very small quantities.

*E. Oxidability by the Air.*

9. THE chemists who have hitherto spoken of the tungsten metal, agree in considering it as very easy to be oxidized. It is not known, however, whether it burns when exposed to the air; but when heated with the contact of that fluid, it appears to change very speedily into a yellow oxide, which becomes blueish by a stronger heat, tinges vitreous fluxes white, or blue, and speedily passes to the state of tungstic acid by a more advanced oxidation. The proportion of oxygen which it absorbs before it becomes oxidized or acidified, has not been determined. Citizen Guyton found that its oxide adheres strongly to vegetable colours, and fixes them.

*F. Union with Combustibles.*

9. It is absolutely unknown whether there be any possible combinations between azote, hydrogen, carbon, and the metallic tungsten. Neither are those combinations better known, which, doubtless, it is capable of forming with phosphorus and sulphur. The small quantities hitherto obtained, have not admitted of trials being made, except with a few of its metallic alloys,

alloys, because this kind of attraction has afforded a more easy means of its reduction. It is known, that when united with iron and with silver, with which it easily combines, it changed their properties in a very singular manner,

*G. Action upon Water and the Oxides.*

10. NOTHING has yet been done to ascertain the changes which water and the various oxides might be capable of by tungsten. Nothing, therefore, can yet be assumed in this respect to characterize this new metal so little known, which has hitherto been obtained in a very small quantity: its easy oxidability, and its great tendency to become acidified, show, that it would seize oxygen from several other oxides.

*H. Action upon the Acids.*

11. THE first, and the only assays which have yet been made upon the mutual action of tungsten and the acids, and which are few, as well as most of what has been done respecting this metal by Messrs. D'Elhuyar, show that this metal is insoluble, and almost intractable by the three most powerful acids, the sulphuric, nitric, and muriatic; and that it is only slightly attacked by the nitro-muriatic acid.

12. If

12. If this singular resistance to the strongest or most decomposable acids were well founded with regard to tungsten, it would show a resemblance to gold and platina. Nevertheless, I must observe, that this unchangeableness does not agree with what the same chemists have affirmed respecting the oxidability of this metal by the air, assisted by caloric, and consequently, that it deserves to be confirmed and established by new experiments. Nothing has yet been observed respecting the action of the oxygenated muriatic acid, which acts on the most obstinate metals, and ought by easily oxidizing this metal to convert it into tungstic acid.

I. *Action on the Bases and the Salts.*

13. METALLIC tungsten has not yet been treated by the earthy and alkaline bases, nor by the salts; we may, nevertheless, conclude from the action of nitric acid, if not upon the metal, at least, upon its first oxide, which it speedily acidifies, that the nitrates and the super-oxygenated muriates, assisted by an elevated temperature, would cause it to pass to the state of acid; and that performed, would afford tungstates as the results of this action.

K. *Uses.*

K. *Uses.*

14. NOTHING has yet been observed respecting the uses of a metal so little known or examined as tungsten. No trial has yet been made with regard to its useful properties. We may even fear, that its reduction and fusion being so difficult, would render it so intractable as not to be used but with great difficulty.

Nevertheless, it is proper that we should indulge in the hope that the arts being at some future period directed to this metal still so new, and of which nature offers so abundant a quantity in the ore called wolfram, may discover processes of greater simplicity than those we yet possess to obtain the metal in the large way; and we may indulge an expectation at the same time, that this metallic substance may become very useful in many operative processes. This conclusion very naturally presents itself from the few properties already discovered in tungsten, namely, its considerable hardness, its partial ductility, in which it approaches to zinc, its infusibility, even its unchangeableness by acids, and the property of its oxide to unite with vegetable colouring matters, to render them fixed and not liable to change. Chemists ought, therefore, to redouble their efforts in the examination of this metal, of which the history must be considered as scarcely brought to an out-

outline. We shall find, that the acid has been much more attentively examined.

## SECTION II.

### *Concerning the Tungstic Acid.*

1. AS Scheele and Bergmann, in their examination in 1781 of the heavy stone or tungsten of the Swedes, discovered that it is composed of lime, saturated with a peculiar acid: as their discovery has since been confirmed by various chemists, and particularly much extended by the researches of Messrs. D'Elhuyer, which by showing the presence of this acid in wolfram, has afforded means to chemists of procuring it more abundantly; it is not astonishing, that the properties of the acidified tungsten should have been much more studied than the metallic tungsten, and that we should possess a greater mass of knowledge respecting the one than the other.

2. It was very natural to designate this acid by the name of tungstic, after the Swedish word, which represents its native combination with lime. In the French nomenclature the G is expunged from the word, to render the pronunciation more soft and easy.

3. This acid is not artificially composed, because nature presents it in the tungstate of lime and of iron. The first is treated by reducing it  
to

to very fine powder, dissolving the lime by the nitric or muriatic acid, and afterwards with alkalis, which dissolve the acid: the alkaline solutions of the tungstates are precipitated by the nitric or muriatic acid; and this precipitate is the solid tungstic acid which is kept to be formed into new combinations. It may be extracted from the native tungstate of lime, in the quantity of 0, 68.

4. The tungstic acid may also be obtained from the tungstate of lime by another process, for which we are indebted to Scheele, as well as for the foregoing. It consists in fusing in a crucible, one part of tungstate of lime with four parts of carbonate of pot-ash: the latter unites with the tungstic acid, while the carbonic acid seizes the lime; so that the product of this fusion is a mixture of tungstate of pot-ash which is soluble, and of carbonate of lime. This mass is lixiviated with twelve parts of boiling water, and upon the solution nitric acid is poured, and the precipitated acid is afterwards well washed. The residue of the aqueous solution contains carbonate of pot-ash and tungstate of lime, not yet decomposed. The former is separated by nitric acid, and the undissolved portion is again treated with four parts of carbonate of pot-ash. In this manner an exact analysis of native tungstate of lime may be made.

5. In order to extract the tungstic acid from the tungstate of lime and native manganese, this ore is mixed in powder with two or three times  
its

its weight of nitrate of pot-ash. This mixture is detonated by projecting it, a spoonful at a time, into an ignited crucible, or by heating it in a vessel sufficiently large to prevent its boiling over. When the detonation is finished, the matter is lixiviated in distilled water, which dissolves the tungstate of pot-ash thus formed, and from this solution the tungstic acid is precipitated in the form of a white powder, by an excess of muriatic acid, and this powder must be washed with water till the fluid comes off tasteless. The latter preparation is rather more difficult, and frequently affords an acid rather less pure, than the former; but by treating it with the muriatic acid, it may be deprived of all its manganese and iron, and reduced to a very white and pure state. The abundance of tungstate of iron in France, where the tungstate of lime has not yet been found, must engage the French chemists to bring these processes for extracting the tungstic acid to perfection. It contains it in the proportion of 0,64.

6. The tungstic acid thus prepared, has the form of a white powder, of a sharp metallic and weakly acid taste. Its specific gravity indicated by Bergmann, is 3,600. It reddens the tincture of turnsole.

7. When heated by the blow-pipe, the tungstic acid first becomes yellow, then brown, and at last black. It emits no fumes, nor does it exhibit any sign of fusion. When it is calcined  
for

for a time in a crucible, it loses its quality of being dissolved in water.

8. It undergoes no perceptible change in the air: It is soluble in twenty parts of boiling water, and a portion separates by cooling. This solution is sour and reddens the tincture of turnsole.

9. When heated with charcoal it passes again, though with difficulty, to the metallic state: with sulphur it becomes grey, without reduction, as is also the case with phosphorus. It precipitates the alkaline sulphurets of a green colour. It appears to be decomposable by various metals; for if a small quantity of muriatic acid be added to its solution in water, and a few drops be laid upon a polished plate of zinc, tin, or iron, it leaves a blue spot. The same blue colour is manifested when those metals are plunged in its solution.

10. The acids do not dissolve the white and pulverulent tungstic acid, but they alter its properties in a remarkable manner, which is not yet well understood. The boiling sulphuric acid renders it blue, in which property it resembles the molybdic acid; the nitric and muriatic acids cause it to assume a fine yellow colour. In this last state the tungstic acid, according to the observation of Messrs. D'Elhuyar, loses its taste, its solubility, and acquires, with a much greater specific gravity, the property of forming with the bases, salts, which are different from



from those of the white acid. The Spanish chemists were of opinion, that the white acid before described, is a triple acidulous salt, and that the yellow is the pure tungstic acid. But there is one observation which proves, that in this yellow state it has lost its four taste, contrary to the first assertion, which is not in other respects supported by sufficient experimental proofs. The yellow colour which the tungstic acid assumes with the nitric and muriatic acids, is one of its most evident specific characters.

11. The tungstic acid, forms with barites an insoluble salt, as well as with magnesia. When its solution is thrown into lime-water it affords a precipitate of tungstate of lime, similar to that found in the native state, and as insoluble. With pot-ash a salt is obtained which affords very small crystals; tungstate of soda has not yet been described or announced. When saturated with ammonia the tungstic acid forms a salt which crystallizes in very small needles, from which the volatile alkali escapes by the action of fire. It changes into a dry yellowish powder; the ammoniacal tungstate decomposes the nitrate, and the muriate of lime, and precipitates them in the form of insoluble tungstate of lime. Its combinations with alumine and zirconia have not yet been examined.

12. The tungstic acid does not precipitate or decompose the salts, but by double elective attraction. The solutions of the alkaline tung-

states form in this manner precipitates of earthy tungstates in the solutions of the sulphates, nitrates, and muriates of lime, alumine, magnesia, and barites. It melts with the phosphates and borates, to which it gives a white or a green colour.

13. It does not act as a solvent on the metals; nevertheless it oxidises iron, by giving out its oxygen, and becoming blue.

14. It is not yet of any use. Citizen Guyton has already proposed means of rendering it useful by uniting it to vegetable colouring matters, which it has the property of fixing and rendering solid. We shall again treat of this property.

#### ARTICLE IV.

##### *Concerning Molybdena and its Acids.*

#### SECTION I.

##### *Concerning the Metal Molybdena.*

##### *A. History.*

1. THE name of molybdena which was formerly synonymous with that of plumbago or black lead, or the natural combination of iron and charcoal, or carburet of iron, else-

VOL. V.

K

where

where to be treated of, is at present given to a brittle and acidifiable metal of which the ore was confounded with that coaly substance. Though Pott, Quist, and some other chemists, originally pointed out some differences in the properties of the ore of molybdena, and the carburet of iron, most naturalists had not sufficiently distinguished these two substances. Many considered them as one and the same substance, and they were sold under the same denomination till Scheele, in 1778, published in the volumes of the Stockholm academy a memoir in which he showed that the substance called molybdena is very different from the carburet of iron, and contains a combination of sulphur, with a substance which he took for a peculiar acid. Pelletier since repeated all his experiments, and added many others, in a memoir published in the *Journal de Physique* 1789, in which he proves that the molybdena of the mineralogists is a combination of a peculiar Metal and sulphur, and that by treating it in several different methods, all of which separate the sulphur and oxygenate the metal, Scheele had formed and not obtained the acid. At the same time he not only confirmed the discoveries of Scheele respecting the molybdic acid, but he pointed out many of its properties which had escaped the Swedish chemist. Since these experiments which have been admitted and verified by all chemists the metal has been named molybdena; in the methodical nomenclature

clature its ore is called sulphuret of molybdena, and its acid, the molybdic acid.

*B. Physical Properties.*

2. THE metal molybdena is extremely rare, and very difficult to be obtained. As in separating the sulphur from its ore it oxidizes, and very easily becomes acidified, it is necessary afterwards to decompose its acid, and deprive the metal of its oxygen. Scheele when he made this experiment with great care using various solvents, never could succeed in obtaining it in the metallic state, the results of his operations having been only a black powder without coherence, and without brilliancy. Bergmann in 1781, in his dissertation on the metallic acids announced and wrote the same year to Citizen Guyton, that Doctor Hielm, formerly his pupil had succeeded in reducing this acid, and collecting a sufficient quantity of metallic molybdena to ascertain its true character; but since this notice nothing has been published, neither on the process of Hielm, nor the metal obtained by his experiments. Pelletier, in his experiments on the reduction of the oxides and acid of molybdena did not obtain a metallic bottom, but an agglutinated, blackish, friable mass, possessing the metallic brilliancy, in the fracture of which small round brilliant greyish grains are discernable; this metal ap-

pears to be extremely infusible; its specific gravity is about 6,000.

*C. Natural History.*

3. MOLYBDENA has not yet been found except in the state of sulphuret and that of acid. As in this latter state it is found in the form of salts combined with the metallic oxides, it must be treated under those metals with the oxides of which it is found combined.

4. The sulphuret of molybdena, which has long been confounded, as before noticed, with the carburet of iron, differs nevertheless from it in many respects. It is less greasy to the touch, more hard, less granulated, more brilliant, less dull, and considerably more inclining to blue. As it is formed of large scaly plates, lying one upon another, with little adhesion, which may be separated from each other, or even cut with a knife, it soils the fingers less than the carburet of iron, and leaves upon paper blueish, or silvery-grey traces, less deep and coloured than those of plumbago. It is difficult to pulverize on account of the elasticity of its plates. Scheele succeeded in this operation by adding crystallized sulphate of pot-ash to it in the mortar, which he afterwards washed off; its powder is blueish. Citizen Haüy adds to its distinctive characters the following properties: the sulphuret of molybdena communicates to resin the vitreous electricity

tricity by friction, whereas the carburet of iron communicates none, at least, when its metallic mark is left. It forms on pottery strokes of a yellowish green, whereas those from the carburet of iron have its ordinary colour. M. Kirwan estimates that the proportions of the component parts of sulphuret of molybdena are 0,55 of sulphur, and 0,45 of metal.

5. As chemists have examined the sulphuret of molybdena much more than the metal itself, I am obliged in each of the following numbers to point out the few notions I have been able to collect respecting molybdena, and the alterations which its sulphuret undergoes by each agent. For want of information respecting the metal, I shall, in a certain manner, fill the vacancies of its history by announcing the properties of sulphuret of molybdena; and I shall observe in this respect that, by separating the effects manifestly due to the sulphur of which I shall speak, the others are really phenomena, owing to the metal itself.

#### D. *Affay and Metallurgy.*

6. THE sulphuret of molybdena may be distinguished manifestly, and without error, after having ascertained the physical properties before described, together with that when treated by the blow-pipe, it emits sulphur, distinguishable by its smell, and white fume, which condenses upon the neighbouring cold bodies in plates

plates or crystallized needles, of a yellowish flame, which becomes blue by contact of the interior flame.

7. The sulphuret of molybdena is not treated in the large way, as its only use is occasionally in its native state, or pulverized, instead of carburet of iron, the true purpose of which it never answers.

#### *E. Oxidability by Air.*

8. MOLYBDENA, heated with the contact of the air, is changed at an elevated temperature into a white volatile oxide, crystallized in brilliant needles, which speedily acquire the acid properties. The proportion of oxygen which this metal absorbs in its oxidation has not yet been determined. This oxide, heated with combustible bodies, assumes a dark blue colour, of little brilliancy, approaching towards the metallic state.

9. The sulphuret of molybdena, calcined in a large crucible, covered with a vessel of the same kind, afforded Pelletier white brilliant needles, which rise in sublimation like those of antimony, and which he found to possess acid characters. Sulphur was disengaged before this matter sublimed.

#### *F. Union*

*F. Union with Combustible Bodies.*

10. MOLYBDENA unites very well with sulphur by heat, and again forms the sulphuret of molybdena. Its union with phosphorus is not known. It unites with the metals, and renders them granulated, greyish, and very friable.

*G. Action of Water and the Oxides.*

11. THE action of molybdena, or its sulphuret, upon water and the metallic oxides, is unknown.

*H. Action of Acids.*

12. THE action of molybdena on the various acids has not yet been appreciated. It is only known that boiling sulphuric acid oxides it, and the nitric acid converts it into molybdic acid.

13. Scheele and Pelletier have better determined the actions of some of the acids upon the sulphuret of molybdena. The boiling sulphuric acid affords sulphureous acid, and oxides the metal. The nitric acid distilled from this sulphuret burns the sulphur, and acidifies the metal. Scheele, by treating one part of the sulphuret of molybdena five successive times, with six parts of nitric acid, a little diluted with water each time, obtained in the retort a white powder, which was a mixture of sulphuric



phuric acid and molybdic acid. The muriatic acid has no action either on the metal or its ore. The arsenic acid, heated in the retort with sulphuret of molybdena, burns the sulphur into sulphureous acid, converts a portion of the metal into the molybdic acid, leaves another portion in the state of metal, and itself becomes converted partly into metal and partly into sulphuret of arsenic. Pelletier made use of this experiment to prove that molybdena possesses the metallic state in its ore.

#### SECTION I.

##### *Action on the Solifiable Bases and the Salts*

14. THE alkalis dissolve molybdena, and favour its oxidation, which, in general, is very easy. By means of fire, in the dry way, they form with the sulphuret of molybdena an alkaline sulphuret, which retains the metal in solution. This action has been little examined, and the effect of the earthy matters on molybdena, or on its ore, has not at all been inquired into.

15. Among the salts there is only the nitrate of pot-ash, of which the mode of action upon sulphuret of molybdena has been determined; but its effect on the metal is still unknown. One part of this ore, and four parts of nitre, detonate in a crucible at a red heat, and afford  
a reddish

a reddish mass. This mass by lixiviation leaves about 0.02 of red oxide of iron, and affords in the solution sulphate of pot-ash, undecomposed nitre, and molybdate of pot-ash, which prove that the sulphur and the molybdena, both being oxygenated to their maximum, or acidified, have united with the base of nitre.

### K. Uses.

16. As we have hitherto obtained but a small portion of molybdena, it has not yet been treated, except slightly, in the way of chemical examinations; it has not been applied to any use. The sulphuret of molybdena is sometimes substituted in the arts for the carburet of iron, with which it is confounded in commerce; but, as has been before observed, it answers the purpose of that substance very imperfectly; so that we may affirm, that its uses are yet unknown. When it shall be more correctly examined, and its properties rendered more familiar, it is not improbable but that it may enter into some alloys, and that its blue or yellow oxide may be used as a pigment.

## SECTION II.

### *Concerning the Molybdic Acid.*

1. WE have already seen that we are indebted to Scheele for the discovery of the molybdic acid;

phuric acid and molybdic acid. The muriatic acid has no action either on the metal or its ore. The arsenic acid, heated in the retort with sulphuret of molybdena, burns the sulphur into sulphureous acid, converts a portion of the metal into the molybdic acid, leaves another portion in the state of metal, and itself becomes converted partly into metal and partly into sulphuret of arsenic. Pelletier made use of this experiment to prove that molybdena possesses the metallic state in its ore.

#### SECTION I.

##### *Action on the Salifiable Bases and the Salts*

14. THE alkalis dissolve molybdena, and favour its oxidation, which, in general, is very easy. By means of fire, in the dry way, they form with the sulphuret of molybdena an alkaline sulphuret, which retains the metal in solution. This action has been little examined, and the effect of the earthy matters on molybdena, or on its ore, has not at all been inquired into.

15. Among the salts there is only the nitrate of pot-ash, of which the mode of action upon sulphuret of molybdena has been determined; but its effect on the metal is still unknown. One part of this ore, and four parts of nitre, detonate in a crucible at a red heat, and afford  
a reddish

a reddish mass. This mass by lixiviation leaves about 0.02 of red oxide of iron, and affords in the solution sulphate of pot-ash, undecomposed nitre, and molybdate of pot-ash, which prove that the sulphur and the molybdena, both being oxygenated to their maximum, or acidified, have united with the base of nitre.

### K. Uses.

16. As we have hitherto obtained but a small portion of molybdena, it has not yet been treated, except slightly, in the way of chemical examinations; it has not been applied to any use. The sulphuret of molybdena is sometimes substituted in the arts for the carburet of iron, with which it is confounded in commerce; but, as has been before observed, it answers the purpose of that substance very imperfectly; so that we may affirm, that its uses are yet unknown. When it shall be more correctly examined, and its properties rendered more familiar, it is not improbable but that it may enter into some alloys, and that its blue or yellow oxide may be used as a pigment.

## SECTION II.

### *Concerning the Molybdic Acid.*

1. WE have already seen that we are indebted to Scheele for the discovery of the molybdic acid;

phuric acid and molybdic acid. The muriatic acid has no action either on the metal or its ore. The arsenic acid, heated in the retort with sulphuret of molybdena, burns the sulphur into sulphureous acid, converts a portion of the metal into the molybdic acid, leaves another portion in the state of metal, and itself becomes converted partly into metal and partly into sulphuret of arsenic. Pelletier made use of this experiment to prove that molybdena possesses the metallic state in its ore.

#### SECTION I.

##### *Action on the Soluble Bases and the Salts*

14. THE alkalis dissolve molybdena, and favour its oxidation, which, in general, is very easy. By means of fire, in the dry way, they form with the sulphuret of molybdena an alkaline sulphuret, which retains the metal in solution. This action has been little examined, and the effect of the earthy matters on molybdena, or on its ore, has not at all been inquired into.

15. Among the salts there is only the nitrate of pot-ash, of which the mode of action upon sulphuret of molybdena has been determined; but its effect on the metal is still unknown. One part of this ore, and four parts of nitre, detonate in a crucible at a red heat, and afford  
a reddish

a reddish mass. This mass by lixiviation leaves about 0.02 of red oxide of iron, and affords in the solution sulphate of pot-ash, undecomposed nitre, and molybdate of pot-ash, which prove that the sulphur and the molybdena, both being oxygenated to their maximum, or acidified, have united with the base of nitre.

### K. Uses.

16. As we have hitherto obtained but a small portion of molybdena, it has not yet been treated, except slightly, in the way of chemical examinations; it has not been applied to any use. The sulphuret of molybdena is sometimes substituted in the arts for the carburet of iron, with which it is confounded in commerce; but, as has been before observed, it answers the purpose of that substance very imperfectly; so that we may affirm, that its uses are yet unknown. When it shall be more correctly examined, and its properties rendered more familiar, it is not improbable but that it may enter into some alloys, and that its blue or yellow oxide may be used as a pigment.

## SECTION II.

### *Concerning the Molybdic Acid.*

1. WE have already seen that we are indebted to Scheele for the discovery of the molybdic acid;

phuric acid and molybdic acid. The muriatic acid has no action either on the metal or its ore. The arsenic acid, heated in the retort with sulphuret of molybdena, burns the sulphur into sulphureous acid, converts a portion of the metal into the molybdic acid, leaves another portion in the state of metal, and itself becomes converted partly into metal and partly into sulphuret of arsenic. Pelletier made use of this experiment to prove that molybdena possesses the metallic state in its ore.

#### SECTION I.

##### *Action on the Salifiable Bases and the Salts*

14. THE alkalis dissolve molybdena, and favour its oxidation, which, in general, is very easy. By means of fire, in the dry way, they form with the sulphuret of molybdena an alkaline sulphuret, which retains the metal in solution. This action has been little examined, and the effect of the earthy matters on molybdena, or on its ore, has not at all been inquired into.

15. Among the salts there is only the nitrate of pot-ash, of which the mode of action upon sulphuret of molybdena has been determined; but its effect on the metal is still unknown. One part of this ore, and four parts of nitre, detonate in a crucible at a red heat, and afford  
a reddish

a reddish mass. This mass by lixiviation leaves about 0.02 of red oxide of iron, and affords in the solution sulphate of pot-ash, undecomposed nitre, and molybdate of pot-ash, which prove that the sulphur and the molybdena, both being oxygenated to their maximum, or acidified, have united with the base of nitre.

### K. Uses.

16. As we have hitherto obtained but a small portion of molybdena, it has not yet been treated, except slightly, in the way of chemical examinations; it has not been applied to any use. The sulphuret of molybdena is sometimes substituted in the arts for the carburet of iron, with which it is confounded in commerce; but, as has been before observed, it answers the purpose of that substance very imperfectly; so that we may affirm, that its uses are yet unknown. When it shall be more correctly examined, and its properties rendered more familiar, it is not improbable but that it may enter into some alloys, and that its blue or yellow oxide may be used as a pigment.

## SECTION II.

### *Concerning the Molybdic Acid.*

1. WE have already seen that we are indebted to Scheele for the discovery of the molybdic acid;



acid; but it may at the same time be remarked, that though this skilful chemist was the first who prepared the acid, its discovery was really contaminated by an error, since he supposed that he had simply extracted the molybdic acid from its ore, which is still called molybdena by all mineralogists; and since he considered this ore as a true compound of the acid with sulphur and a small quantity of iron. The doctrine of the French chemists has ascertained and corrected this error, by showing to Citizen Guyton, to Pelletier, and to all the authors or partisans of the pneumatic theory, that in the various experiments of Scheele, in which he obtained the molybdic acid, he really produced or formed it by burning the molybdena, and charging it with the whole quantity of oxygen it was capable of absorbing.

2. Though the molybdic acid appears to exist in nature, as Mr. Klaproth has obtained it from yellow lead ore, it has always been prepared or fabricated artificially, by treating the sulphuret of molybdena, the only ore of this substance yet known, by several oxygenating processes.

3. There are four processes known and practised to convert the molybdena contained in its ore or native sulphuret, into molybdic acid. The first consists in its oxidation by fire and air. Scheele had observed, that when a fragment of sulphuret of molybdena is heated in the flame of the blow-pipe upon a plate of silver, the white fume which it emits attached itself

self to the plate in a thin scale of a yellowish brilliant white, which was the true molybdic acid. But this method produced only a few particles. Pelletier has greatly extended it by directing that the same operation be made in a crucible covered with another vessel of the same kind. The white brilliant prisms which sublime in this experiment, are the molybdic acid. But this method is tedious, requires strong heat, and does not afford very pure acid, It is not therefore to be preferred.

4. The second process is performed with nitric acid, and is one of the most certain. Upon one part of the sulphuret of molybdena, five parts of this diluted acid are to be poured; the distillation is then to be carried on to dryness, and a mixture of nitrous gas and nitrous vapour is obtained with much froth; this distillation is to be repeated three or four times, employing five parts of the same acid every time. At the end, the dry residue is as white as chalk, and consists of the molybdic acid mixed with the sulphuric acid. The nitric acid has burned the sulphur, and acidified the molybdena by yielding its oxygen to it, and decomposing it. The dry residue is to be washed with hot water, by which means the molybdic acid is obtained pure and concrete. The water made use of, carries off a small portion of this acid, together with the sulphuric acid; and when it is strongly evaporated, it assumes a blue colour which announces

nounces the decomposition of its acid, and its transition to the metallic state.

5. In the third process, the sulphuret of molybdena is distilled with the arsenic acid. There is no action between these two bodies while any water is present; but when the water is passed over and the fire is raised, arsenic and the sulphuret of arsenic sublime; the sulphureous acid passes over, and the concrete molybdic acid remains in the retort. But this acid is not pure; it is mixed with arsenic and sulphuret of arsenic.

6. The fourth process is the most expeditious of all, and would deserve to be preferred to them if it afforded the acid in a state of purity. It is the product of the detonation of nitre with the sulphuret of molybdena. Three parts of nitrate of pot-ash, and one part of sulphuret of molybdena, well pulverized and well mixed together, are thrown into an ignited crucible. After the detonation, the residue is a reddish mass composed of the oxide of iron, sulphate of pot-ash, and molybdate of pot-ash. By lixiviating it in water the two salts are dissolved, and the oxide of iron remains. The solution is evaporated to obtain sulphate of pot-ash, and sulphuric acid is poured into the liquor which refuses to crystallize, and which must be diluted with a small quantity of water, until by the addition of more acid, no further perceptible precipitate falls down. We must, nevertheless observe, that this acid does not completely

pletely decompose the molybdate of pot-ash, and that the acid which falls down is the acidulous molybdate of pot-ash, of which the properties essentially differ from the pure molybdic acid. I have described this process merely to show the particular result and the existence of this molybdic acidule. We must conclude, that the true and the only means of obtaining the pure molybdic acid consists in the second process, or the treatment of sulphuret of molybdena by the nitric acid.

7. The molybdic acid prepared by the operations before pointed out, particularly by the second process, is a white powder, of a sharp metallic taste. Its specific gravity, according to Bergmann is 3,400.

8. When heated in a large glass retort it affords, by a strong fire, a small quantity of sulphureous acid, which proves that it cannot be deprived of that acid but with the greatest difficulty. But it undergoes no other alteration by this treatment than a commencement of fusion. In a well-closed crucible it is fused by a strong heat, adhering to the sides of the vessel in a glassy covering; and it crystallizes in red radii, which issue from the centre by the cooling. If the crucible be uncovered at the moment of fusion, it rises in a white fume by contact of the air, and this vapour attaches itself in brilliant scales of a golden-yellow colour upon the surrounding cold bodies. This fume disappears, and the volatilization ceases the moment the apparatus is closed:

closed : hence it follows, that the contact of the air is the immediate cause, and therefore, there is no sublimate according to Scheele, found in the crucible which serves as a cover. It appears, either that Scheele did not apply sufficient heat, or that a small quantity of air introduced itself into the experiment of Pelletier. His sulphuret of molybdena was burned and acidified.

9. Most combustible bodies decompose the molybdic acid. Carbon reduces it by the assistance of heat into a black powder which approaches the metallic state, and wants only the aggregation by fusion to be true molybdena. By heating with three parts of sulphur, there is a disengagement of sulphureous acid, and sulphuret of molybdena is formed. Several metals heated with this acid, also reduce it, themselves becoming partly oxidized, and partly combined in alloys with the molybdena.

10. Hot water easily dissolves it ; one part of this acid requires about five hundred parts to dissolve it ; this solution is very acid and sharp ; it reddens turnsole, precipitates the alkaline sulphurets, and decomposes soap. After its fusion, it is equally soluble ; in which respect, it differs from the tungstic acid. The solution of the molybdic acid becomes blue when iron or tin are kept plunged in it ; it effervesces with the alkaline carbonates ; it precipitates the solutions of nitrate, of muriate, of barites. The molybdic acid becomes much more soluble

ble with a small portion of alkali, by forming acidulous molybdate.

11. The concentrated sulphuric acid dissolves much molybdic acid by the assistance of heat; it becomes violet and blue as it cools. The muriatic acid also dissolves a great quantity by ebullition. By distilling to dryness, a part of the acid sublimes of a blue and white colour. The residue is grey and deliquescent, like the sublimate. The same phenomenon is seen even in the fume of molybdena produced by the blow pipe, for the interior flame colours those fumes blue. The nitric acid does not affect the acid of molybdena.

12. The molybdic acid easily unites with the alkaline and earthy bases, and forms salts of sparing solubility with the latter, but very soluble and crystallizable with the alkalis. Scheele has said very little concerning the properties of the alkaline and earthy molybdates, which are still almost entirely unknown. The calcareous molybdate is not rendered yellow by the nitric acid. The molybdate of barites is somewhat soluble in water; the ammoniacal molybdate is decomposable by fire. There is an acidulous molybdate of pot-ash; and Scheele, without denoting it by a particular name, points out, nevertheless, its characters different from those of the pure molybdic acid. I shall distinguish it here on account of its differences, and because, it is frequently obtained instead of the pure acid.

13. The

13. The acidulous molybdate of pot-ash, is obtained either by precipitating the product of the detonation of nitre and sulphuret of molybdena by the sulphuric acid, or by directly uniting molybdic acid with a small quantity of pot-ash, as if to render it more soluble. This salt affords small irregular crystals by cooling its saturated boiling solution; the acid which is greatly in excess, is not, however, volatile by an open fire, as it is when alone. The acidulous molybdate of pot-ash is much more soluble than the molybdic acid, since it requires only four parts of boiling water; it is also more fusible. It may be decomposed by throwing into its hot concentrated solution a small quantity of nitric acid, which retains its alkali, and precipitates the molybdic acid in small crystals. The same acidule does not decompose the sulphate of pot-ash by the assistance of fire, like the pure acid.

14. The molybdic acid strongly heated with most of the sulphates, and particularly with that of pot-ash, disengages a small portion of sulphuric acid, because it forms in this case the acidule of molybdena; accordingly, the sulphuric acid does not decompose the molybdate of pot-ash, but to the point of producing the same acidule, as I have already remarked. It likewise decomposes the nitrates, and disengages the nitrous acid by heat. The muriates are also decomposed, and a portion of the white, yellow, or violet molybdic acid sublimes, which attracts  
4 moisture,

moisture, is resolved into a fluid in the air, and becomes blue on the metals. These two decompositions of the nitrates and the muriates, the nitrous acid which is disengaged from the former, and the deliquescent state of a portion of molybdic acid, seem to announce that it is capable of becoming surcharged with oxygen, receiving modification by this super-oxygenation; nevertheless, it appears to super-oxygenate the muriatic acid which is distilled from it, since it becomes blue by this action. Further experiments are wanting on this point.

15. The molybdic acid is not yet of any use; it has hitherto been only an object of research and curiosity with chemists. The example of the tungstic acid, of which Citizen Guyton has already determined a useful property for dyeing, ought to engage chemists to attend to the molybdic acid under the same point of view.

## ARTICLE V.

### *Concerning Chrome and its Acid.*

#### SECTION I.

#### *Of the Metal Chrome.*

##### *A. History.*

1. THE analysis of a mineral made by other means, and with more care than hitherto had been applied to its examination, presented in



December, 1797, to Citizen Vauquelin, the discovery of this new metal. The red lead of Siberia appeared to him, from several previous examinations, to offer properties, which he had not observed in any other substance. After having made a series of experiments upon this ore, which, unfortunately, is very scarce, and little abundant in our cabinets, he ascertained, that it is formed of oxide of lead and 0,36, of a new acid which Bindheim, and several other chemists took for molybdic acid; but, which differs greatly from it, instead of resembling its properties, as we shall speedily see. The following is the account of its discovery :

2. By treating the Siberian red lead with two parts of carbonate of pot-ash dissolved, which he boiled in two hundred parts of water, the pot-ash seized the new acid while the carbonic acid united with the lead. The new salt was found in solution in the water, and the carbonate of lead at the bottom in the form of white powder. He precipitated the acid of the new salt by means of nitric acid, which seized the pot-ash. The red lead of Siberia, when treated with the muriatic acid, was totally dissolved, assuming a beautiful deep red colour; the liquor by evaporation, afforded muriate of lead; the supernatant fluid which preserved its fine green colour, contained the oxide of the new metal disacidified by the muriatic acid, and having, by that means, passed from the orange-red colour to green.

B. *Phy-*

*B. Physical Properties.*

3. The acid obtained by the first process, and the oxide produced by the second, were both reduced by Citizen Vauquelin, by strongly heating them in a crucible of charcoal; he obtained a metal different from all those yet known, which we have agreed to name chrome, on account of its remarkable property of forming a very coloured acid, and itself giving colour to all its saline combinations.

4. Since this first discovery, Citizen Vauquelin has found this metal, 1st. In a green oxide united to lead in crystals of the same colour, which are almost always found in the same locality as the Siberian red lead. 2dly. Also in a green oxide in the emerald of Peru, of which it is the true colouring matter. 3dly. In the acid form in the spinelle ruby, to which it gives the beautiful red tinge it possesses. M. Tassaert, a Prussian chemist, who is charged with the operations of the laboratory of the school of the mines at Paris, has since found the chromic acid combined with iron in an ore of the department of Var, near Toulon.

5. The metal extracted by this process, is of a white colour inclined to grey, very hard, very brittle, and extremely difficult of fusion. The small quantity which Citizen Vauquelin could procure, did not permit him to ascertain many of its properties.

speed, and that it may, by that means, be made to acquire all the properties it possesses in the Siberian red lead.

*I. Action upon the Bases and the Salts.*

12. It is entirely unknown whether it is capable of alteration by the earths and alkalis; it does not easily unite with them, unless in the state of acid, for in that of green oxide it is not soluble. This green oxide is even obtained by the caustic fixed alkalis, by separating it from the alumine with which it is united in the emerald, to which alumine the alkalis unite without touching the oxide of chrome.

13. We are not at all acquainted with its action on the salts.

*K. Uses.*

14. It is hardly to be imagined, that so recent a discovery can have yet been applied to any use. Nevertheless, its author has already observed, that its oxide may be used in the fabrication of glass and enamel, and it may even, perhaps, have been already employed without suspecting it, in the mixtures of the products of minerals ill understood or analyzed, of which it may form a part. The manufacturers of porcelain are often in this situation, when they prepare oxides from very mixed ores in order to obtain variety of shades. The nature of these shades

shades depends on unknown alloys, of which the chrome may well be one of the constituent parts,

## SECTION II.

### *Concerning the Chromic Acid.*

1. THOUGH the chromic acid has been very lately discovered, and has not yet been examined, except in very minute quantities, by the different processes to which Citizen Vauquelin has subjected it, it is nevertheless better known, and affords more facts to the history of chemistry than chrome itself. This arises from its being found native in combination with the oxide of lead, so that it was much more easy to extract it and ascertain some of its properties, than to perform the same with regard to the metal which has not yet been obtained, except with the greatest difficulty, and in much less quantity.

2. The chromic acid extracted from the red lead of Siberia, treated by the carbonate of pot-ash, and disengaged from this alkali by a stronger acid, has the form of a red or yellow orange powder, of a peculiarly sharp metallic taste, more perceptible than that of any other metallic acid.

3. When exposed to the action of light and caloric in open vessels, it becomes green; in close vessels it affords pure oxygen, and passes to  
thg

the state of green oxide by losing its acidity. The red lead of Siberia itself gives out oxygen gas, when heated in close vessels, and assumes a yellowish-green colour. The chromic acid is the first metallic acid known which is capable of disacidifying itself so easily by the action of caloric, and affording oxygen gas by this simple operation. We shall see, that many of its properties depend on the slight adherence, at least, of a portion of its oxygen. The green oxide of chrome passes again to the state of chromic acid only, when treated by the acids which restore its oxygen.

4. The action of most of the combustible bodies on the chromic acid, is yet unknown. It is only known, that when strongly heated with charcoal it becomes black, and soon passes to the metallic state without fusion; the facility with which it permits its oxygen to escape, shows that it may be decomposed by hydrogen, phosphorus, and sulphur.

5. The chromic acid is soluble in water, and crystallizes by cooling and evaporation, in prisms of a ruby-red colour. It appears to be capable of uniting with many metallic oxides.

6. Among the acids, none has a more remarkable action upon it than the muriatic. When this acid is distilled by gentle heat from the chromic acid, the latter passes speedily to the state of oxygenated muriatic acid; consequently, it acquires by this mixture, the property of dissolving gold. By this property it resembles the nitric acid,

acid, in consequence of the weak adherence of its oxygen. It must be remarked, that it is the only one of the metallic acids which exhibits this character.

7. The chromic acid unites very easily with alkaline matters. It forms with them solutions of an orange or yellow colour, which afford orange crystals by evaporation. It is the only acid which has the property of colouring its salts; which circumstance has induced us to denominate it the chromic acid, preserving the name of chrome from its metallic radical. We are not yet acquainted with the earthy chromates, nor with the specific properties of the alkaline chromates, nor the order of attraction of the acid for its bases. We only know that the earthy chromates are insoluble, or much less soluble than alkaline chromates.

8. We are equally unacquainted with the action of the chromic acid upon the salts, whether it be capable of decomposing some of them, as we have seen in the other metallic acids. It appears, at least, that this decomposition cannot operate but by virtue of a very elevated temperature, or the double elective attractions, since the sulphuric, nitric, and muriatic acids, decompose the chromate of pot-ash, and precipitate the chromic acid from its solution.

9. As the action of the chromic acid upon the metals has not yet been appreciated, I can say nothing of its combination with arsenic, tungsten, and molybdena, nor of the order of the  
the

the state of green oxide by losing its acidity. The red lead of Siberia itself gives out oxygen gas, when heated in close vessels, and assumes a yellowish-green colour. The chromic acid is the first metallic acid known which is capable of disacidifying itself so easily by the action of caloric, and affording oxygen gas by this simple operation. We shall see, that many of its properties depend on the slight adherence, at least, of a portion of its oxygen. The green oxide of chrome passes again to the state of chromic acid only, when treated by the acids which restore its oxygen.

4. The action of most of the combustible bodies on the chromic acid, is yet unknown. It is only known, that when strongly heated with charcoal it becomes black, and soon passes to the metallic state without fusion; the facility with which it permits its oxygen to escape, shows that it may be decomposed by hydrogen, phosphorus, and sulphur.

5. The chromic acid is soluble in water, and crystallizes by cooling and evaporation, in prisms of a ruby-red colour. It appears to be capable of uniting with many metallic oxides.

6. Among the acids, none has a more remarkable action upon it than the muriatic. When this acid is distilled by gentle heat from the chromic acid, the latter passes speedily to the state of oxygenated muriatic acid; consequently, it acquires by this mixture, the property of dissolving gold. By this property it resembles the nitric acid,

acid, in consequence of the weak adherence of its oxygen. It must be remarked, that it is the only one of the metallic acids which exhibits this character.

7. The chromic acid unites very easily with alkaline matters. It forms with them solutions of an orange or yellow colour, which afford orange crystals by evaporation. It is the only acid which has the property of colouring its salts; which circumstance has induced us to denominate it the chromic acid, preserving the name of chrome from its metallic radical. We are not yet acquainted with the earthy chromates, nor with the specific properties of the alkaline chromates, nor the order of attraction of the acid for its bases. We only know that the earthy chromates are insoluble, or much less soluble than alkaline chromates.

8. We are equally unacquainted with the action of the chromic acid upon the salts, whether it be capable of decomposing some of them, as we have seen in the other metallic acids. It appears, at least, that this decomposition cannot operate but by virtue of a very elevated temperature, or the double elective attractions, since the sulphuric, nitric, and muriatic acids, decompose the chromate of pot-ash, and precipitate the chromic acid from its solution.

9. As the action of the chromic acid upon the metals has not yet been appreciated, I can say nothing of its combination with arsenic, tungsten, and molybdena, nor of the order of  
the



the attractions between this acid and those of the metallic radicals, of which the order of the present work would otherwise require me to treat in this place. The chromic acid, as well as the green oxide of chrome, promises to be very useful, either alone or combined with the other metallic oxides, to painters, enamellers, glass-makers, in the imitation of precious stones, and, perhaps, even in dyeing.

#### ARTICLE VI.

##### *Concerning Titanium.*

##### *A. History.*

1. IN 1795, the third year of the French republic, Mr. Klaproth, a chemist of Berlin, having examined a fossil from Boinik in Hungary, known by the name of red schorl, on account of its prismatic or fluted columnal form, discovered that it was the native oxide of a metal till then unknown. He characterized it by the following properties, which are in fact, the most marked and the most distinctive of any it possesses. By calcination, it passes from white to yellow, and from yellow to red; it affords a yellow enamel, assumes blue, yellow, and violet colours, by the vitreous fluxes before the blow-pipe; is very greedy of oxygen; is precipitated by the sulphurets; affords a thick  
brown

brown precipitate of a reddish colour, resembling blood, by the nut-gall. Though he did not succeed in reducing this oxide, and obtained only brown scoria towards the bottom, and a greyish blue at the top, yet, as its properties leave no doubt respecting its metallic nature, he gave it the name of titanium, an insignificant term, as he himself admits, but, on that account, not calculated to give any false notion.

2. Towards the end of the same year citizens Miché and Cordier, officers of the mines of the French Republic, discovered in the canton of Saint Yriez, in the department of Haute Vienne, a red schorl in small broken masses, rolled and worn at their surface, interspersed among the soil of the fields. It had long been used in the manufacture of Sevres to make the brown colour on porcelain; but its use was laid aside on account of the extreme difficulty of obtaining an uniform tint. Citizens Vauquelin and Hecht undertook a very extensive chemical examination; they verified and confirmed the discovery of M. Klaproth; added some new facts, particularly a greater degree of precision; and they succeeded in approaching much nearer than he did to the reduction of this metal, so that they have described several properties of metallic titanium, of which the Berlin chemist made no mention. They have, therefore, supplied me with many new details and results for this article, which is founded entirely on their experiments as well as those of M. Klaproth.

*B. Physical*

*B. Physical Properties.*

3. THE metallic titanium obtained in the manner to be mentioned, exhibits not a true well-fused button, but an agglutinated brittle, blackish-brown, cavernous mass, crystallized within, hard and brittle, almost always wholly or in part of a reddish colour, or of a bright shining reddish-yellow at the surface, equally brilliant and red in its internal cavities, frequently covering the surface of the crucibles with a lining of the same shade, changing and assuming rain-bow colours or purple when exposed very hot to the air, volatile and attached to the cover of the crucibles with that red colour by the strong fire employed in its reduction. It is the only metal which so much approaches the tinge of copper, though this is mixed with yellow.

*C. Natural History.*

4. TITANIUM is not yet known in the native state, but in the form of oxide. Two species are distinguished. A. The red pure oxide of titanium, named red schorl, found in Hungary, Spain, France, and Mount Saint Gothard. The latter was found by M. de Saussure, who named it Sagenite on account of its crystals having the form of reeds or fillets, *sagena*. It is dif-  
feminated

feminated in long brilliant needles, and included in the rock-crystal of Madagascar. The form of its molecule is a triangular prism, with rectangular isosceles bases. It is obtained in the primitive form by dividing the nucleus, in the direction of the diagonals of the bases of its crystals. These are hexahedral prisms, with dihedral summits resembling those of Saint Yriez, or octagonal fluted prisms, like those of Hungary, or square prisms like those found a few years ago near Pont-James les Noyers, between Nantes and Ingrand. These crystals are grouped two and two, and crossed like crystals of tin under an angle of  $114^{\circ}$ . Its colour is red, more or less deep, clear and brilliant, and even semi-transparent on its edges. It easily breaks; but its hard fragments are difficult to pulverize. It scratches glass. Its specific gravity is between 4,180, and 4,246. B. The siliceo-calcareous titanium, or the titanite of Klaproth. It is a fossil composed of oxide of titanium, flint and lime nearly in equal parts; its specific gravity is 3,510. Before the blow-pipe it only undergoes some blisters at its surface. It is found at Passau in small right rhomboidal prisms, terminating in dihedral summits in a gangue composed of feldt-spar and quartz.

D. *Assay*

soluble in acids nor effervesces with them; carbonic acid, and a small quantity of oxygen gas is disengaged. When heated alone by the blow-pipe upon charcoal it becomes of a fine orange-yellow, which disappears by cooling, and it becomes black at the surface which touches the coal. These changes of colour are owing to the loss of the different proportions of oxygen.

*F. Treatment with Combustible Bodies.*

10. No trial has yet been made to combine titanium with combustible bodies.

11. The native red oxide, treated with carbon by a strong fire, as we have seen, becomes reduced into blackish agglutinated grains, covered with a red and very brilliant metallic pellicle.

15. The carbonate of titanium has not been assayed, but by carbon mixed with the saline fluxes, and by strongly heating those mixtures, a reduced metallic mass was obtained without fusion, at least without complete fusion, the surface of which was red and brilliant, and of which the internal cavities were frequently lined with prismatic crystals similar to those of the oxide of manganese. When the crucible breaks in this experiment, the matter spread about, applies itself to the surface in a metallic plate of the finest purple-red, similar to a leaf of jewellers foil, which circumstance

stance announces a species of fusion in the reduced titanium sufficiently manifest, though it has never yet been obtained in a collected button, for want of vessels to support the heat, without themselves becoming fused at a temperature above 166 degrees of Wedgwood's thermometer.

13. Neither titanium, nor its native oxide, nor its artificial carbonate, have yet been treated with hydrogen, phosphorus, sulphur or any other metallic substance.

*G. Treatment with Water and the Oxides.*

14. THE action of titanium upon water and the metallic oxides has not yet been tried; so that we cannot state its rank of attraction for oxygen. There was no motive to examine that of the artificial carbonate of titanium on these bodies. It was known that it is not soluble in water since it was separated from the alkaline carbonate formed by this liquid; and it was more natural to try the native oxide with the metallic oxides, with the intention that by adding the reducing substances, the titanium might be obtained by the common reduction of the metallic alloy.

15. The memoir of citizens Vauquelin, and Hecht, contains several experiments of this assay of the native oxide of titanium with various metallic oxides, with charcoal, oil, or black flux, and exposed to a violent heat. That

with the oxide of lead, and a fourth of the former; was found disseminated in grains, in a blackish brown mass not fused; that of arsenic six parts to one of the oxide of titanium afforded a black glass, compact and well fused without appearance of metallic matter; that of copper in equal parts, afforded only a greenish grey scoria, under which was found a small button of pure copper; that of silver also in equal parts afforded a deep green, blistered scoria, interspersed with small grains of silver, covering a button of the metal in a state of purity, and very ductile. The oxide of iron in equal parts, and half of the native oxide of titanium, afforded in several successive assays, by the assistance of a very active flux, indications of alloy between the two metals. This alloy which was well reduced, but did not flow into a button, was of a grey colour, mixed at its surface, and in its interior showed brilliant metallic particles of a gold and yellow colour. We see therefore, that titanium unites very difficultly, or even not at all with lead, arsenic, copper, and silver, but that it appears capable of uniting with iron.

#### H. Treatment

*H. Treatment with the Acids.*

16. THE experiments with the acids were much more numerous, and presented results much more interesting than most of the other experiments on titanium. Mr. Klaproth has well described the inefficacy of these solvents on the red native oxide of titanium, and their action upon the carbonate of that metal. Citizens Vauquelin and Hecht have shown with greater care and accuracy, the effects they produce on the metallic titanium and its artificial carbonate. As the most remarkable characters of this new metal consist in those various effects; I shall here describe them sufficiently at length to give an accurate knowledge of the same.

17. Titanium (numbers 3 and 5) treated with concentrated and boiled sulphuric acid, afforded sulphureous acid gas, and was changed into a white oxide, part of which remained dissolved in the acid. This solution presented all the characters of the solution of carbonate of titanium in the same acid which will speedily be mentioned; there is, consequently, no doubt, as Citizens Vauquelin and Hecht remarked, that the red metallic substance, obtained by the reduction of the native oxide, is the metal titanium.



18. The nitric acid long boiled upon this metal, did not exhibit any remarkable effect; nevertheless, the brilliant points of this metal were changed into a white substance, which shows, that they were oxidized at their surface.

19. The muriatic acid diluted with water, afforded much hydrogen gas with titanium in blue scoria. [We must here observe, that the portion of red titanium which was only a superficial coating, was too small in quantity to be submitted in this state to the action of all the acids]; a considerable quantity of white flakes was formed in the liquor. The nitro-muriatic acid converted it speedily into a white powder, which was dispersed through the fluid, and the surface of the metal was also at first covered with a similar white pellicle. We shall soon see, that this suspension of oxidized titanium by the decomposition of water in the muriatic acid, is similar to what happens between the carbonate of this metal and the same acid.

20. Mr. Klaproth treated the native red oxide of titanium from Hungary, with the sulphuric, nitric, muriatic, and nitro-muriatic acid, digested with heat for a considerable time upon this oxide in powder. There was no perceptible action, and the oxide remained without alteration. Citizens Vauquelin and Hecht, by treating the same red oxide of titanium from St. Yriez, observed, that the sulphuric acid concentrated and boiled, detached merely a few perceptible indications of iron, without changing  
the

the oxide; that the nitric acid was equally ineffectual, and the muriatic acid produced only a slight modification in the colour which became rather grey.

21. This is not the case with the carbonate of titanium obtained by fusion of its native oxide with carbonate of pot-ash in the experiments of Mr. Klaproth, as well as in the more multiplied experiments of Citizens Vauquelin and Hecht. All the acids act in a singular manner upon this carbonate, and it is evident, that this is owing, as these last chemists observed, to the absorption of oxygen and carbonic acid occasioned by the fusion with the carbonate of pot-ash. It is true, that it is a remarkable circumstance to find a native oxide not saturated with oxygen, which does not take that principle by the action of the nitric acid, but becomes charged with it by fusion with the carbonate of pot-ash. We should be tempted to think with Mr. Klaproth, that it rather lost a portion of oxygen in this fusion which it naturally contained, and which might render the native oxide insoluble in acids, if the experiments of Citizens Vauquelin and Hecht did not compel us to draw a contrary inference from the facts they have so carefully observed.

22. Mr. Klaproth asserts, that the carbonate of titanium, which he calls white earth of this metal, obtained by the action of the carbonate of pot-ash upon the red schorl, is totally soluble by heat in the sulphuric acid diluted with  
water,

water, and that this clear solution, when evaporated, becomes converted into a white gelatinous and opaque substance. In the experiments of Citizens Vauquelin and Hecht, the carbonate of titanium, which was boiled with sulphuric acid at  $40^{\circ}$ , produced an effervescence and gave a milky appearance to the fluid; many white flakes similar to curds in milk were formed; a stronger heat completed the solution and afforded a transparent liquid; this solution did not afford crystals.

23. According to Mr. Klaproth, the nitric acid formed with the carbonate of titanium a transparent solution, which becomes of an oily appearance in the air, and affords transparent crystals in elongated rhombs, as if truncated in two opposite points, so as to represent hexagonal plates. Citizens Vauquelin and Hecht observed somewhat more in this operation. The carbonate of titanium, according to them, effervesces strongly with concentrated nitric acid: when the mixture is heated, the nitrous acid is disengaged; the fluid remains continually milky; sugar added to the mixture precipitates an oxide which is whiter than the carbonate was. If diluted nitric acid be used, the oxide of titanium is dissolved, but the solution becomes turbid by heat. Caloric, therefore, opposes the combination of this oxide with the nitric acid, by oxidizing the metal still more, and by that means renders it insoluble in the acid,

24. In

24. In the experiments of Mr. Klaproth, the carbonate of titanium was soluble in the muriatic acid; and this solution formed a yellowish and transparent jelly, in which he observed many transparent cubical crystals. The experiments of Citizens Vauquelin and Hecht present still more information respecting this singular compound. The carbonate of titanium was dissolved with effervescence in the concentrated muriatic acid, and assumed a deep yellow colour while it was dissolving, without the assistance of heat; the solution was yellow, though saturated, it was constantly acid; when heated, it became reduced into a flocculent magma, which was not re-dissolved by the addition either of water or of more muriatic acid. A similar solution, which was not heated, remained transparent; at 60° of heat it afterwards became a transparent yellow, of a very styptic acid taste: by cooling of this jelly it deposited many small crystals, which effloresced in the air. When this solution was boiled, oxygenated muriatic acid escaped; the oxide precipitated by heat was no longer soluble in the muriatic acid; and the chemists before cited, proved that this fact is owing to a disoxidation, because it becomes capable of being again dissolved without heat, after it has been long boiled with the nitric acid. The contrary, therefore, takes place, in this instance, to what happens with the nitric solution; the oxide of titanium requires to be strongly oxidized in order  
to

to unite with the muriatic acid; and in this state it is only soluble at a cold temperature, because the acid, when heated, seizes a portion of its oxygen, and renders it insoluble. The oxide of titanium, when too highly oxygenated, cannot be dissolved in nitric acid; and when this last solution is strongly heated, the titanium, by decomposing the nitric acid, and seizing oxygen from it during the disengagement of nitrous gas, becomes separated from the acid, and renders the solution of a milky whiteness. When therefore it is supercharged with oxygen, it is soluble without heat in the muriatic acid, and becomes disoxidized by the application of heat. The oxide of titanium, separated from the muriatic acid by the action of the blow-pipe, assumes a beautiful lemon-yellow colour.

25. The solutions of the oxide of titanium in the acids are precipitated by the carbonate of pot-ash, and by ammonia, in white flakes, by the prussiate of pot-ash, of a grass green, mixed with brown, by nut-gall of a reddish-brown, resembling the colour of blood, by the arsenic and phosphoric acid in white powder. The muriate of titanium in which tin is plunged, becomes first of a pale red colour, and afterwards of a ruby-red; zinc changes its yellow colour to a violet, which passes to that of indigo. Heat destroys these fine colours. The muriatic solution of titanium is not rendered turbid by water, charged with sulphurated hydrogen. The sul-

fulphuret of ammonia colours it of a dirty green, and forms a precipitate of a bluish green; the white carbonate of titanium, or the white oxide separated from the acids, becomes also coloured of a greenish blue, when the sulphuret of ammonia is poured in. All these facts, curious for the beauty of the spectacle, and the variety of the phenomena, were discovered by Mr. Klaproth, and verified by Citizens Vauquelin and Hecht. They have added the following fact; that the light green precipitate, formed in the muriate of titanium by the prussiate of pot-ash, passes through brilliant shades of purple, blue and white, where it stops, when it is decomposed in the midst of the fluid in which it was obtained by the addition of alkalis.

*H. Treatment with the Alkaline Bases and the Salts.*

26. THE action of the alkalis and the salts upon titanium are not known; it appears to be capable of oxidation by the nitrates and the super-oxygenated muriates.

27. The native red oxide of titanium, heated with four parts of pure pot-ash, melts and becomes divided at the same time that it assumes a white colour; the division which the alkali produces in it renders it soluble in the acids, though it is not so in its natural state of density.

28. When heated by the blow-pipe with phosphate of soda and ammonia, this native oxide melts with ebullition, and affords a black globule

bule when entire; but of which the fragments are violet. With borax, it affords a yellow green compound inclining to brown. Similar shades, but brighter, clearer, and more transparent, are obtained by treating the carbonate of titanium with the same salts; which appears to depend on being then deprived of the small portion of iron which it contains in its native state.

29. We have already observed, that when in a crucible, heated with six parts of carbonate of pot-ash, the native red oxide of titanium melts, becomes greenish, and that by diluting this mass in water, this fluid dissolves the caustic alkali, and leaves the carbonate of titanium infinitely more divided than it was in its native state. This result proves, that the oxide of titanium when heated, has a stronger attraction for carbonic acid than pot-ash has, from which it seizes it; and as an hundred parts of the oxide weighed 157, after this operation, though the carbonate of titanium loses only 0,25, of carbonic acid by calcination, it is evident, that the oxide of titanium besides the carbonic acid, has also absorbed near 0,11 of oxygen during its treatment with the alkaline carbonate. This accurate experiment induced Citizens Vauquelin and Hecht to suppose contrary to the opinion of Mr. Klaproth, that by the effect of its alkaline fusion, the native oxide of titanium becomes more burned than before, and in consequence of that process, becomes more soluble in the muriatic

tic acid. We must, nevertheless add, that its state of division also contributes to render it soluble, since, by heating it, and merely depriving it of carbonic acid, the simple concentration, or condensing of its particles, is sufficient to deprive it of its solubility.

#### K. *Uses.*

30. It is scarcely to be presumed, that titanium can become useful in its metallic form so long as no means shall be discovered of completely reducing and fusing it; and this last point appears very difficult to be obtained, because this metal appears to be no less, but probably even more infusible than platina. In its state of oxide, particularly when purified and attenuated by fusion with the alkalis, it may be used with much advantage to colour enamels pottery and porcelain. It is also used to afford a fine strong yellow on the porcelain of Berlin; and though it has been rejected as a brown at the manufacture of Sevres, where it was never found to afford a uniform tinge, this no doubt arises from the operators having taken the native oxide in which a portion of iron may cause the vitrification and shade to vary; but when purified and more oxidized, it may be used to compose a brilliant yellow colour as is found to be the case at Berlin. Besides which, when its state of oxidation is varied and it is mixed with other oxides, we may expect to obtain violet, orange,



orange, brown, and green colours of a variety of tints.

## ARTICLE VII.

### *Concerning Uranite.*

#### *A. History.*

1. IN the month of October 1789, a letter of Mr. Crell, inserted in the Journal of Physic, informed the French chemists, that Mr. Klaproth, of Berlin, had discovered in the pech-blende and green glimmer of Saxony, a new semi-metal which he named uranite. It was announced, that this metal was more difficult to reduce than manganese, that its external colour was grey, and that internally it inclined to a light brown; that its specific gravity was 6,440, its brilliancy scarcely considerable, and its hardness moderate; that it could be scraped and filed; that its oxide afforded by the assistance of a flux, a deep orange colour for porcelain.

2. In April 1790, the dissertation of Mr. Klaproth on this new metal was inserted entire in the same journal. The following is the order in which the author has arranged his work; it is divided into twenty-nine paragraphs.

The first paragraph exhibits the opinion of authors respecting the pech-blende of George Wagsfort,

Wagsfort, John at Georgenstadt. Mr. Werner, ranked it among the ore of iron; and suspected that it consisted of a combination of tungstic acid with metal.

In the second paragraph, the ore of the new metal is carefully described and distinguished into two varieties: the first of a steel grey, having the specific gravity 7,500, mixed with particles of sulphuret of lead; the second blacker, more brilliant, less hard, accompanied with yellowish earth, mixed with square green plates of glimmer, or green mica.

In the third, he examines the pech-blende by the blow-pipe without addition, and with saline flux.

In the fourth, he treats it in the retort and by roasting; he obtained sulphureous acid and sulphur; he observes, that when the vessel is open, it increases in weight after having lost its sulphur.

In the fifth, he examines it by the sulphuric and by the nitric acid, which dissolves it better and separates the sulphur.

In the sixth, he treats it by the muriatic and the nitro-muriatic, which separates the sulphur, develops the lead, and affords crystals of salt formed by the new metal.

In the seventh, he describes some properties of its nitric and nitro-muriatic solutions.

In the eighth, he speaks of its precipitations by the prussiate, and by the alkalis, which are constantly yellow.

In

In the ninth, he announces those precipitates which form the carbonates.

In the tenth, he shows the solubility of the new metal precipitated from its solutions by the acids; it is greater than that of the ores.

In the eleventh, we find that pech-blende is insoluble in the alkalis.

In the twelfth, the oxide by precipitation is examined by the blow-pipe, and by the fluxes; the author speaks of unsuccessful attempts to reduce it by means of the fluxes.

In the thirteenth, and fourteenth, he describes the successive processes by which he succeeded best in this reduction.

In the fifteenth, renouncing the expectation of ascertaining the properties of this new metal in the metallic state, he examines the colour which its oxide may be capable of giving to glass and to porcelain.

In the sixteenth, concluding from all the experiments before described, that pech-blende contains a new metal, he names it uranium, assuming after the manner of the ancient philosophers, the name of the new planet discovered by Herschel, Uranus.

In the seventeenth, he examines the native metallic oxide of uranite in a pure state, which is found in the mine of George Wagsfort, and is the yellowish earth mentioned in his second paragraph.

In the eighteenth and nineteenth paragraphs, he refers to the ores of uranite, the glimmer,

or green mica, which is found at the place last mentioned, and at Eibenstock, which Bergmann supposed to be muriate of copper, and was called calcholite by some mineralogists, but is merely the oxide of uranite coloured by the oxide of copper; some specimens contain no copper, and have the yellow colour of wax. At the end of his dissertation, he concludes that we must place uranite as a new genus among the brittle metals of difficult fusion. He distinguishes three species, 1. The sulphureous uranite, of which there are two varieties, the first of a deep grey mixed with sulphuret of lead; the other black, resembling pit coal. 2. The uranite of a yellow, and, as it were, earthy oxide. 3. The uranite crystallized in square plates, of which there is one variety pure and yellow, and the second tinged green by the oxide of copper.

#### *B. Physical Properties.*

3. I HAVE given this historical notice at some length, because I was desirous of showing the difficulties Mr. Klaproth found in reducing his new metal, and the impossibility of describing its properties in the present state of our knowledge, at the same time that the necessity of examining the properties of its oxide becomes more evident. I shall observe, that the word uranium, adopted by the chemist of Berlin, and hitherto translated into French by the term  
uranite,

uranite, appears to me as well as to Citizen Guyton, much better adapted to our language by converting it into the term urane, which I shall hereafter use.

4. If we condense the notions we possess respecting the physical properties of uranite, of which the ores have hitherto been very scarce, and which no French chemist has yet obtained metallic, for want of the subject; we shall find, that this metal has not been obtained except in a mass slightly coherent, consisting of small agglutinated globules, like many of the preceding metals. Its colour of a deep grey, exhibits a pale brown when scratched. It has little brilliancy, on account of the porosity of this agglutinated mass. It may be scraped with a knife or worn by the file. It is as it were, intractable and infusible.

#### *C. Natural History.*

5. Three species of the ores of uranite are at present distinguished.

A. The first is the sulphuret of uranite; it is black, of various depths of shade, shining in its fracture, and sometimes lamellated; this is the pech-blende of several mineralogists; its specific gravity is between 6,37, and 6,53. Mr. Klaproth gives its specific gravity 7,50. The sulphuret of zinc with which it has been confounded, weighs only 4,16. It contains, as it should appear, little sulphur; it often affords  
iron,

iron, and sulphuret of lead. The uranite exists in the metallic state. Mr. Klaproth has distinguished two varieties.

B. The second is the native oxide of uranite. It always exists in the form of yellow powder at the surface of the sulphuret; there are brown or blackish varieties, on account of the oxide of iron which is mixed with it; some mineralogists have given it the name of uranochre in this state. Its specific gravity is 3,24. When it is of a pure, equal, and bright yellow, it may be used in chemical experiments as a pure oxide of uranite.

C. The third ore of this metal is the native carbonate of uranite. There are two very distinct varieties; one of a pale green, and sometimes even of a silvery white, according to Mr. Klaproth: this contains little or no oxide of copper; it is very scarce: the other is of a deep very brilliant green; it is the green mica, glimmer, chalcholite, or brass stone of authors. It has sometimes been taken for mica, sometimes for sulphate of barites, and sometimes for a muriate of copper. Mr. Klaproth has pointed it out as an oxide of uranite mixed with the oxide of copper. It has since been found to contain carbonic acid. It is crystallized in small square plates, with double chamfers at their edges, that is to say, in nascent octahedrons, and not truncated, as so many mineralogists have falsely asserted. Sometimes, though very seldom, it is

Vol. V. N found

found in complete octahedrons, Mr. Klaproth mentions it as existing in the cubic form.

The native uranite has not been found either in alloys, or with its oxide combined with any other acids except the carbonic.

#### *D. Assay and Metallurgy.*

6. THERE are no regular assays of the ores of uranite, and still less, of metallurgic works on this metallic substance, which has only been found in small quantities in Saxony. Mr. Klaproth having to a certain point succeeded in extracting the metal, we may consider it, and I shall here describe his process as a docimastic method. The yellow oxide of uranite precipitated from its solutions by an alkali having been mixed with honey and oil to form a paste, he burned the mixture in a test: a black powder remained, which had lost rather more than one fourth of its weight; this was put into a lined and well-closed crucible, and exposed to heat in a porcelain furnace in contact with another crucible, containing as terms of comparison, oxide of manganese treated in the same manner. After the operation of the heat, the latter was well reduced; but the oxide of uranite was beneath the powder of charcoal in a coherent mass, friable between the fingers in a black shining powder, which decomposed the nitric acid with effervescence, in the form of red vapour: whence, Mr. Klaproth concludes that the oxide

of uranite was reduced, but without fusion, because it is still less fusible than manganese. The same uranite in black powder was placed in a lined test covered with calcined borax, and then well-closed. He exposed this vessel to the hottest part of the porcelain furnace: this treatment afforded him the metallic mass, consisting of very small agglutinated globules.

7. With regard to the assays, the following details, which belong rather to the oxide than to the metal, will explain the processes.

#### *E. Oxidability by the Air.*

8. URANITE ignited in the fire with exposure to air, or by the flame of the blow-pipe, underwent no change, so that it appears to be difficult of combustion and oxidation. In an assay with phosphate of soda and ammonia, the surface of the globule became grass green.

9. The yellow oxide of uranite does not melt; it becomes of a brownish grey when long heated in contact with the air. It is not known whether it loses or gains oxygen by this process.

#### *F. Treatment with Combustibles.*

10. WE have seen that this oxide is reduced by charcoal with heat. No experiment has yet been made to unite uranite with sulphur, though it is very probable that its ore might be artificially formed in this manner. Neither is its combina-



tion with phosphorus known. It appears, that uranite combines readily with it since Mr. Richter, by treating the oxide of uranite with bullocks blood and a forge-heat, obtained a button similar to cobalt in its colour, very short and brittle which as Mr. Gren thinks, was manifestly phosphorated, and owes its great fusibility to the phosphorus which it contains.

11. We have no knowledge respecting the alloys of which titanium may be susceptible, and we find no experiment relating to this object among those of Mr. Klaproth.

#### *G. Action upon Water and the Oxides.*

12. THE same observation applies to its action upon water and the metallic oxides; these have not been appreciated, neither can we say any thing respecting its comparative attraction for oxygen.

#### *H. Treatment with the Acids.*

13. EXCEPT the decomposition of the nitric acid by uranite, in the black brilliant powder which I have already mentioned in the article of assay, there is no fact yet known concerning the mutual action of this metal and the acids; but the action of these burned bodies upon the oxide of uranite has been better appreciated; the principal part of the labours of Mr. Klaproth's inquiry consists in this, and the most remarkable characters

characters of the metal here treated are thus ascertained.

14. The yellow oxide of uranite is readily dissolved in the sulphuric acid diluted with water, and affords by evaporation, a salt of a lemon colour, in small prisms united in bundles. This sulphate of uranite differs in its colour, its form, and its other properties from all the known metallic salts.

15. The nitric acid also dissolves the oxide of uranite with much facility; the solution by gentle evaporation affords large crystals in hexagonal tables of a light or yellowish green, which are very regular. This nitrate of uranite is one of the most beautiful metallic salts we know of.

16. The muriatic acid also dissolves the oxide of uranite, and, according to Mr. Richter, affords small yellowish crystals of muriate of uranite, which are deliquescent.

17. The fluoric acid combines with this oxide, dissolves it, and forms a crystallized salt unchangeable in the air.

18. The phosphoric acid united to the oxide of uranite, forms yellowish white flakes slightly soluble in water.

19. Arsenical acid unites with this oxide by decomposing the nitrate of uranite by the alkaline arseniates. A precipitate of whitish yellow is thus obtained.

20. The molybdate of uranite is also obtained according to Mr. Richter, in powder of a yellow  
low

low white, with brownish reflections, by pouring the solution of molybdate of pot-ash into the nitrate of this metal.

21. The acid solutions of the oxide of uranite are precipitated by the alkaline sulphurets in a brownish yellow, and their surface is at the same time covered with a grey metallic pellicle: the infusion of nut-gall thrown into one of these solutions, of which the excess of acid has been absorbed by an alkali, forms a chocolate-brown precipitate. Zinc, iron, and tin plunged in the solution separate nothing, and produce no modification in its colour, either with or without heat. The fixed alkalis precipitate from these solutions a lemon-yellow coloured oxide of uranite. Ammonia affords a yellower precipitate; the alkaline carbonates separate a carbonate of uranite of a white yellow, which is re-dissolved in an excess of the precipitants.

#### *I. Treatment with the Bases and the Salts.*

22. THE fixed alkalis do not dissolve uranite nor its oxide in the humid way, even at the boiling heat; the oxide merely assumes a deep brown colour. The alkaline carbonates, on the contrary, dissolve it easily, and the acids precipitate from these solutions an oxide of a clear yellow colour.

23. The oxide of uranite combines with the saline fluxes, and communicates different colours to them according to their nature, proportion, and

and state. Among others, the following colourations are known.

A. Eight parts of prepared filex, four parts of pot-ash, and half a part of the oxide of uranite afford, by fusion, a glass of a bright transparent brown colour. Soda substituted to pot-ash in this composition, produces a glass of a grey black.

B. One part of the oxide of uranite, eight parts of filex, and the same quantity of calcined borax, afford a glass similar to the smoky topaz.

C. The same proportion of filex, oxide of uranite, and vitreous phosphoric acid afford an apple-green enamel similar to the prase or chryso-prase.

D. Half a part of this oxide, and eight parts of the vitreous phosphoric acid fused together, afford a transparent glass of the colour of the emerald.

#### K. Uses.

24. URANITE has not yet been employed on account of its scarcity, and the few experiments to which it has yet been subjected. It is evident from what has been here stated, and from the observation of the orange colour which its oxide gives to porcelain, that it may be used for the fabrication of coloured glass, enamel, pottery, and porcelain.

## ARTICLE VIII.

*Concerning Cobalt.**A. History.*

1. COBALT, also denominated cobolt occasionally, was unknown to the ancients, who made their blue enamels with certain preparations of iron according to Gmelin, was, as it appears, employed and known for vitrification of a blue colour about the end of the sixteenth century. Preusler in 1571, Jenitz, and Harren in 1575, were the first who established manufactures of glass of cobalt in Bohemia and in Saxony. It was about the year 1732, that Brandt, a Swedish chemist, extracted with some care cobalt from its ores, and announced it to be a peculiar metal, different from all other metals. Lehman, in his *Cadmiology* published in 1761, studied its history and properties with much depth and detail from the time in which he wrote; but his attention was more occupied with its ore and vitreous blue than with the metal itself. Bergmann has added much to what was known before his time; he gave greater accuracy to the works of his predecessors in the examination of this metal. He described its resemblances and differences compared with nickel,

nickel, manganese and iron, to which cobalt considerably approaches, and showed that it is very difficult to purify. Scarcely any thing has been done with regard to it since his time. Most of the systematical authors have treated slightly of it. Macquer in his dictionary of chemistry, has given only half a page of some inaccurate general notions respecting this metal. For the most part it has been too much neglected in chemical works. Some chemists still consider it as an alloy. We shall see how little foundation there is for this opinion.

#### *B. Physical Properties.*

2. COBALT extracted and purified by the processes hereafter to be described, is of a grey colour, inclining to rose or red, of a very fine close granulated texture. Its fracture is rough, and exhibits no indication of plates. It is, easily reduced into very fine powder, which is grey and of little brilliancy. It has always been ranked among semi-metals on account of its brittleness. Its specific gravity is, according to Bergmann 7,700, and according to Citizen Guyton 7,811. This last chemist gives it the sixth rank among the metals for its hardness. He places it, for its property, near tin, after zinc, and gold, and before lead and antimony. It has no determinate taste nor smell, nevertheless, when rubbed for a long time between the fingers it.

it stains them, and leaves a perceptible impression in the mouth and nose.

3. The conducting, electric, and dilatable properties of cobalt have not been comparatively examined with regard to the other metals. Some authors have pretended, that it is magnetic of itself; but it is probable, that this magnetism is owing to a small quantity of iron, which remains almost always alloyed with cobalt, and from which it is very difficult to clear it.

4. Cobalt is one of the most difficult metals to fuse. Nevertheless, it does not approach the infusibility of titanite, uranite, chrome, nor even platina and manganese. Many authors have ranked it with iron on account of this property, and Citizen Guyton, in fact, estimates its fusibility at 130 degrees of the pyrometer of Wedgwood, like that of iron. Mr. Kirwan compares its fusibility to that of copper; but it is much less. It ignites long before it melts. It flows difficultly, or it has only a thick fusion in our furnaces. When suffered to cool slowly, and by decanting the liquid portion from the midst of its mass already fixed on the edges, we find the cavity lined with prismatic crystals, or crystals in needles amassed together, which the lens shows to be placed irregularly one upon the other, like the broken prisms of basaltes. This crystallization succeeds very well, by inclining the crucible, which contains the melted metal, at the moment in which its surface fixes; in proportion-

portion as the liquid portion flows off, the other part which adheres to the congealed mass presents these accumulated prisms.

### *C. Natural History.*

5. We are as yet acquainted, with precision, with only four states of cobalt in nature, or four ores of this metal; for it has never been found pure or native in the earth. In the first, it is alloyed with arsenic both in the metallic state; in the second, the metal is combined with sulphur and arsenic at the same time; the third is an oxide of cobalt, and the fourth an arseniate of the same metal.

6. The first species, arseniated cobalt, commonly called arsenical ore of cobalt, is of a grey, or more or less brilliant white colour, sometimes mixed with red, of a close grain, similar to that of cobalt, without perceptible laminæ in its fracture, and of the specific gravity 7,72; whiter and more brilliant when crystallized than in its irregular pieces, in which last form it imitates the beautiful white of silver. Its varied forms are the smooth cube, the octahedron, the cubo-octahedron, or cube with eight angular facets. The fragments of this arseniated cobalt, plunged in the flame of a candle, emit a vapour, having the smell of garlic: by the blow pipe, this vapour is more abundant, and the heated mass becomes attractable by the magnet; which  
seems



seems to show that this ore contains a small quantity of iron.

7. The second species denominated grey cobalt by Citizen Haüy, because its nature is not yet well determined, but which several mineralogists have called the arsenico-sulphureous ore of cobalt, or cobalt with iron and arsenic, mineralized with sulphur, differs from the preceding by its grey colour of tin, and a slightly yellowish colour internally; by its less specific gravity, which lies between 6,33 and 6,45; by its very laminated structure; by the absence of the vapour, and smell of garlic, when presented to the flame of a candle; by both these properties by the blow-pipe, though less strong than in the arseniated cobalt; and by its not becoming attractable by the magnet, like the former when it has been heated. This ore, of which the form of the nucleus is the cube, affects in its secondary forms the octahedral, dodecahedral, with pentagonal faces, the icosahedral, the cubo-dodecahedral solid, and the cubo-icosahedral solid, like the sulphuret of iron, which is often found mixed with it. The cubo-dodecahedral crystals which are frequently found in this cobalt, have, like those of the sulphuret of iron, their facets rectangular, charged with longitudinal streaks in different directions upon the three faces not parallel to each other. This so remarkable analogy in the form, gives reason to believe, that this ore is a sulphuret of iron containing cobalt. Citizen Haüy observes, nevertheless, that there are varieties of grey  
cobalt

cobalt which are not found among the sulphurets of iron, and among others, that which he names partial grey cobalt, because the cuneiform, or decahedron or octahedron, with two rectangular marginal facets on the extreme edges, result from laws of diminution, which, instead of being repeated on all the parts of the nucleus similarly situated, act only with respect to some of them, and consequently, have only a partial existence. This grey cobalt has not yet been accurately analyzed, though it is the species of ore most frequently employed in some of the arts, and particularly in the manufactures of porcelain.

8. The third species is the black oxide of cobalt, named by mineralogists black cobalt in efflorescence, or vitreous ore of cobalt; it exists in black friable masses similar to scoria, or in a black efflorescence, soiling the fingers and often mixed with oxide of iron. It is a pure oxide of cobalt.

9. The fourth species is the arseniate of cobalt, named by mineralogists, flowers of cobalt, or cobalt in efflorescence. Its colour is lilac-grey or of peach-flower, or vine lees; sometimes in simple efflorescence, sometimes in rosetts formed of needles of a deep colour which they preserve even after pulverization, and sometimes with four-sided prisms terminating in summits of two faces. When heated upon charcoal, it emits a strong odour of garlic, and then loses its colour and becomes black. It is frequently disseminated

rates them. These two metals are obtained in the assay, because the ores of cobalt are very frequently mixed with those of bismuth; but they are not obtained when the ore of cobalt is carefully selected, and accurately separated from that of bismuth. We must observe, that the cobalt thus obtained contains almost always arsenic, nickel, and iron; and we shall hereafter show how it may be purified. Nevertheless, by using well-crystallized grey cobalt, we may procure the metal as pure as possible, by the simple process of reduction here described; the richest ores afford from 60 to 80 per cent. and the poorest only 25.

14. Bergmann and Kirwan have described methods for the humid assay of the cobalt ores. They consist in treating them by the nitric acid, which oxidizes and dissolves the cobalt and the iron; these oxides are precipitated by the carbonate of soda, then washed and separated by the nitric acid, which dissolves that of cobalt, without touching the iron. The ores of cobalt, which contain the oxide of the metal, are easily attacked by the muriatic acid. Those which are difficult to dissolve in the first mentioned acids, are soluble in the nitro-muriatic. Bergmann considered most of the ores of cobalt as containing this metal in the native state; and he did not admit the state of oxide, excepting in the vitreous ore and the arseniate of cobalt.

15. Scheffer advises to ascertain and determine the colouring property of the ores of cobalt,

cobalt, because it is by this property that they are useful to the arts, and for this purpose he directs fusion with three parts of common potash, and five parts of glass in powder; this process is far from being as accurate and useful as it seems to be. It is necessary to separate the sulphur and arsenic by previous roasting, and to oxide the cobalt in order to render it more susceptible of combination with glass: this method even then has little real advantage, because it does not afford an accurate term of comparison between the different matters, vitrified and coloured blue by this oxide. It can only be considered as an approximation of some use to direct works on a large scale.

16. The ores of cobalt are wrought in the large way, but not for the purpose of extracting metal. After pounding and washing the ore, whatever may be its nature, it is roasted in a furnace, which terminates in a long horizontal gallery, constructed of boards, and serving for the use of a chimney; during the roasting, the arsenic is always contained in the ore of cobalt (for we must remark, that it almost constantly happens that two or three of the four species of ores above described, are found together in the veins or masses of cobalt mineral extracted out of the earth); this arsenic oxides and sublimes in the gallery, where it is deposited, one stratum after another, and from whence it is detached from time to time under the name of white arsenic. If the ore be mixed with bismuth, this

metal is reduced, speedily fused, and is collected at the bottom of the furnace; the cobalt remains in the state of black pulverulent oxide, which, when mixed with two or three times its weight of flint, ignited and pounded, forms the kind of grey powder sold in commerce under the name of zafre. This being fused with three times its weight of black flux, a small quantity of oil, or tallow, and muriate of soda, in a lined crucible, is often used in the laboratories of chemistry to obtain the metallic cobalt when its ore is not to be procured. It is necessary, indeed, to use much flux, and a very strong fire, to reduce and liquefy this metal so as to obtain it in the form of a button; it is also frequently impure, by mixture with iron, arsenic, and nickel; bismuth is also separated: so that we ought not to have recourse to this mixed oxide, excepting when we cannot procure the pure ore of cobalt. We may wash it before reduction and fusion in order to carry off the flux, and leave the oxide alone. In this manner near one half of the mass is subtracted, which is earth, and the metallic oxide, remaining after the washing, affords one fourth of its weight of the metal.

*E. Oxidability by the Air.*

17. COBALT oxides without its being necessary to fuse it; for it is sufficient that it be heated and slightly ignited in a shallow vessel, or large test;

it; by agitation in the air, its powder loses its ruddy colour and brilliancy; it first becomes of a deep grey, which gradually becomes black, or rather of a blue, so intense, that it appears black. By a very violent fire this last oxide flows into a blue-black glass. Cobalt fused with the contact of the air, becomes covered with a tarnished pellicle, which is merely a commencement of oxidation, and affords the same black powder when heated and agitated for a long time in the atmosphere.

18. The temperature at which fused cobalt may be inflamed, has not yet been determined. It appears to afford 0,40 of its original weight of oxide by oxidation. Citizen Guyton placed it in the first rank of oxidability, beside manganese, iron, zinc, and nickel. The characteristic and most useful property of its oxide is, that of affording a blue glass by fusion, and of very intensely colouring with the same tinge all the substances with which it may be vitrified; it is easily reducible by charcoal, which takes from it at the red heat, its oxygen; it does not give out this principle by the mere action of caloric or light.

#### *F. Union with Combustibles.*

19. The combination between azote, hydrogen, carbon, and cobalt, is not known, though it is not improbable, that these combinations exist.

20. Pelletier has ascertained the union of cobalt with phosphorus. By projecting small pieces of phosphorus upon cobalt, ignited in small fragments in a crucible, the cobalt immediately becomes fused; in this manner it absorbs about a fifteenth of its weight of phosphorus, and exhibits on its surface a crust of violet rose-coloured oxide. The same phosphoret of cobalt is formed by fusing, in a crucible, a mixture of equal parts of vitreous phosphoric acid and cobalt, mixed with an eighth of their weight of powder of charcoal. In proportion as the acid passes to the state of phosphorus, it unites with cobalt, which becomes melted; and at the bottom the phosphoret of cobalt is obtained, covered with a glass of a beautiful blue. The phosphoret of cobalt, prepared by either of these processes, is exactly the same compound: it is of a bright metallic colour, whiter than cobalt, inclining to blue, brittle, and slightly needled in its fracture. It is more brittle than the metal, and loses its brilliancy in the air; when heated and kept in fusion by the blow-pipe, the phosphorus is disengaged from the metallic globule, and burns on its surface; and at length there remains a vitreous globule of a deep blue; which proves that the cobalt is speedily oxidized by the fusion and combustion of the phosphorus in the air, in proportion as this last principle is disengaged.

21. Sulphur does not unite with cobalt but with difficulty, so that the union with these two combustible

combustible bodies is not known, but they may be combined with the assistance of the alkalis. This metal is soluble in the alkaline sulphurets in the dry way, and the result is a sulphuret, with large facets of a white or yellowish colour, a kind of artificial ore, from which fire disengages the sulphur very imperfectly, and which cannot be decomposed but by the acids.

22. Cobalt, alloyed with many metallic substances, forms granulated and brittle metals; it unites to arsenic, which it retains with great power, and from which it cannot be cleared but with much difficulty.

#### *G. Action upon Water and Oxides.*

23. COBALT acts neither upon water nor upon the metallic oxides, neither has this metal sufficient attraction for oxygen to seize it from those bodies.

#### *H. Action upon the Acids.*

24. ALL the acids attack either cobalt or its oxide. The concentrated and boiling sulphuric acid is decomposed by this metal; sulphureous acid gas is disengaged; a grey dense matter is formed inclining to a rose colour. If this species of magma be lixiviated, water dissolves the sulphate of cobalt, and affords a light grey fluid. The



The green solution described by some authors is owing to nickel, which cobalt sometimes contains; but this colour is never seen with very pure cobalt: the same observation applies to the two kinds of crystals obtained by this solution, which are mentioned by many chemists. The sulphate of cobalt crystallizes in small needles, or in tetrahedral prisms, rhomboidal, terminating in summits of two faces. This reddish salt is decomposable by fire, and also affords an oxide of cobalt slightly grey, or blackish, if urged by a strong heat. It melts, swells up, and boils with noise before the blow-pipe. The alkalis and alkaline earths decompose it, and precipitate an oxide of a yellow colour, inclining to rose or flesh-colour; one hundred parts of cobalt afford an hundred and forty parts of this precipitate by the pure alkalis. When the precipitation is made by the alkaline carbonates, 160 parts of precipitate are obtained from 100 parts of carbonate made use of. The oxide of cobalt in the form of zafre, is easily dissolved in the diluted sulphuric acid, and constitutes a salt similar to that which is prepared with the metal.

25. Cobalt decomposes the nitric acid with effervescence, and disengagement of nitrous gas, particularly with the assistance of a gentle heat; the metal is oxidized and dissolves in the acid. The solution is of a flesh colour, or deep violet; when concentrated it inclines to brown. By cautious evaporation it affords small reddish prismatic crystals, which are deliquescent, and  
boil

boil upon ignited coal without detonation, leaving a deep red oxide after their decomposition by fire. The precipitates of this nitrate of cobalt, by the alkalis, resemble those of the sulphate, excepting that their colour is more lively and brilliant; and accordingly it is from this salt that the oxidized cobalt is almost always precipitated for enamel and porcelain. An excess of alkali re-dissolves this oxide; ammonia more particularly exhibits that property while the precipitate is suspended in the liquor; nevertheless, when it is deposited and condensed, ammonia may be used to dissolve the oxide of nickel, with which it may be contaminated. The nitric acid is of all acids that which the least readily dissolves zafre, or oxide of cobalt, mixed with filix.

26. The muriatic acid does not dissolve cobalt without heat; by the assistance of heat it dissolves a small portion; the gas which is disengaged during this solution has not been observed; it must be hydrogen gas. This acid dissolves oxidized cobalt with great facility; and the more strongly it is oxidized the more effectually is the action. By this action it is that the whole of the oxide of cobalt is taken from zafre by the muriatic acid: this acid also takes it from the sulphuric acid; it forms a solution of a brown red, which by evaporation affords a muriate of cobalt crystallized in small deliquescent needles. This solution is remarkable for the property of becoming of a beautiful green when

when heated ; it constitutes the most striking and the best known sympathetic ink ; it must be diluted with water until colourless. With this fluid writing is made on white paper ; the characters thus formed disappear in drying ; but when brought near the fire, the paper soon exhibits the letters traced of a fine pea-green colour, which disappear in cooling, and still preserve, if they have not been too strongly heated, the property of resuming the green colour by heat. By too much heat the writing becomes brown, and no longer disappears, the paper being scorched. This ink of sympathy is more particularly made with the nitro-muriatic acid and zafre. The cause of this colouration of the muriate of cobalt by heat has not yet been ascertained. It was formerly thought to be merely drying which causes the green colour to appear, and that it disappeared by absorbing the water of the atmosphere ; but this opinion is false, since the solution produces the sympathetic effect, even if the paper on which the writing is made be put into a bottle, and dipped in boiling water, for it assumes the green colour, and loses it in proportion as the water cools : it is more natural to think that this effect depends on dis-oxidation, and that the oxide on cooling resumes the portion of oxygen which it had lost. Some chemists think that cobalt does not form sympathetic ink unless it contains iron ; but this assertion is not proved,



27. Cobalt thrown in powder into the oxygenated muriatic acid gas, takes fire, and burns with white sparks; by this means a pale rose coloured oxide remains, which may be employed in the arts.

28. The phosphoric acid dissolves the oxide of cobalt, and forms a reddish fluid, which becomes turbid, and affords a deposition when the acid is saturated. The fluoric acid which dissolves it also, affords crystals by well-conducted evaporation. The boracic acid has no action upon cobalt; it may be combined with the oxide, by mixing a solution of the nitrate of cobalt with a solution of borax. There exists a carbonate of cobalt, which is formed by precipitating cobaltic salts with alkaline carbonates. We have seen, that an hundred parts of this metal, which afford only 140 of precipitate by the alkalis alone, afford 160 parts by the carbonate of soda.

29. The metallic acids combine with the oxide of cobalt. We are not yet acquainted with the tungstate nor molybdate, nor chromate of cobalt; but the arseniate of cobalt is easily prepared, and well known. It is formed by uniting the nitrate of cobalt with the arseniate of pot-ash, and of soda. Of all the cobaltic salts, this is the most deep and most brilliantly coloured of the rosy red; it very nearly resembles the ore which was described in the fourth species.

*I. Action on the Bases and the Salts.*

30. THE alkalis and the alkaline earths have no action upon cobalt; they completely dissolve, with different degrees of facility, its oxide when suspended or diffused in water; they serve, or at least may be used, to separate those oxides from various substances, and even from other oxides, which are not soluble like this of cobalt, or are less soluble than they in alkaline substances.

31. The earths, and particularly silica, when fused with the oxide of cobalt and fixed alkalis, formed a blue glass of such intensity, that very little of the oxide must be employed to admit of transparency and a perceptible blue colour: if this be not attended to, the glass will be opaque and appears black.

32. There is no action between cobalt and the sulphates. The nitrates burn and oxidize them at an elevated temperature without detonation or perceptible flame, and this action is frequently used to prepare the oxide of cobalt employed in enamels, pottery, and particularly porcelain. The grey ore of the metal may be treated in this manner, after which, the residue of the detonation must be well washed to carry off all the salts, and the rose or flesh-coloured oxide thus obtained, must be long suspended in water, until it be very fine, of great purity, and of a very homogeneous colour. The same effect

effect is obtained by the super-oxygenated muriate of pot-ash, which detonates by percussion, when mixed with one third of its weight of cobalt in powder.

#### K. *Uses.*

33. COBALT is not used in its metallic form ; it is employed only to make blue glasses or enamels. Zafre is used for coarse enamels, common potteries, and earthen ware, in which employ it is mixed with vitreous fluxes. In the manufactories of porcelain, much care is taken to have the oxides of cobalt very pure and attenuated. The grey ore is chosen well crystallized ; this is roasted, and treated with the nitric or muriatic acid, or otherwise it is burned with nitrate of pot-ash ; the oxide is carefully washed with much water : by which treatment, the oxide is obtained in violet-coloured powder, very fine, and very homogeneous, which affords the purest and most beautiful blue, when treated with a vitreous flux. The elegant blue of the porcelain of Sevres, is of this nature.

34. At the manufactories in the vicinity of the cobaltic mines, a vitreous blue is prepared in a fine powder, which, in commerce, is known by the name of azure, or powder-blue. The zafre mixed with flux, is fused with alkali so as to afford a deep blue glass, called smalt. This smalt is reduced to powder in mills, and the powder elutriated in large vessels of water. The first

first portion which falls down is the heaviest, and is called coarse azure. In succession, four other azures of different tenuity are obtained; the last, which is the finest of all, is named azure of four fires. It is particularly used in the preparation of the powder-blue.

35. We must remark, in concluding the history of this metal, that cobalt resembles several of the preceding metals, particularly tungsten and molybdena, in its property of affording a blue colour; nevertheless, the blue afforded by the others is only transient, and does not take place by fusion, whereas, this is constant, and always the product of vitrification. These analogies, and the extreme difficulty of purifying cobalt, have induced several chemists to suppose, that this metal is only an alloy; but it is certain, as Bergmann observes, a man who has carried the philosophy of chemistry to the highest point, that those opinions respecting the pretended alloy of cobalt must be considered as erroneous, so long as there are no possible experiments to prove, that cobalt can be separated into two different metals in known proportions, and that by alloying these metals in the same proportions, true cobalt can be fabricated. As no such proofs exist, the notions of authors in this respect are inadmissible hypotheses, and we must, until these proofs shall be exhibited, consider cobalt as a peculiar metal, possessing very distinct characters and properties not to be observed in any other metal, nor in any alloy whatsoever.

## ARTICLE IX.

*Concerning Nickel.**A. History.*

1. **HIERNE** was the first who mentioned the particular ore which contains nickel, in a work on the art of discovering metals, published in 1694. The ore was named kupfernickel or false copper. Henckel considered it as a species of cobalt, or arsenic mixed with copper. Cramer referred it also to the copper and arsenical ores, though he did not obtain copper from it ; which is also confessed by Henckel.

2. The opinion which classed kupfernickel among the ores of copper, was generally adopted till the middle of the 18th century. In the year 1751 and 1754, Cronstedt, a celebrated Swedish mineralogist, the first who formed the useful project of classing fossils according to their chemical nature, showed, in the Memoirs of the Academy of Stockholm, that a new metal might be extracted from this ore, very different from all those before known, which he named nickel. This opinion was soon adopted by the greater part of mineralogists, though several, and particularly Citizens Monnet and Sage, have continued to support, though without decisive experiments,



periments, that nickel is cobalt alloyed with arsenic, iron, and copper.

3. Bergmann endeavoured to reconcile these opinions by a strict examination of nickel; he gave a dissertation on this metal, in the month of July 1775, under the form of a thesis, supported at Upsal by Mr. Arvidson, his pupil. He particularly endeavoured to determine whether nickel be truly a peculiar metal; and in this examination, he displayed all the resources of the art, and all the skill of a great master. The general result of this great work was, that nickel which does not contain a particle of copper, is usually alloyed with cobalt, arsenic, and iron, which cannot be separated, but with the greatest difficulty; but that, notwithstanding the impossibility of purifying it completely, its properties are in so many respects different from those of all the other metals, and these properties becoming more distinct and intense, in proportion as it is purified, it is absolutely necessary to consider it as a very distinct, and determinate species.

#### *B. Physical Properties.*

4. NICKEL, in the highest state of purity to which it can be brought, is of a yellowish white, or reddish white of variable brilliancy, and granulated texture. This texture is lamellated only in the case of impurity. Its specific gravity approaches nearly to 9000, according to Bergmann.

mann. Citizen Guyton gave it only 7807. Bergmann, in various places, affirms, that it is semi-ductile, and Citizen Guyton ranges it with zinc, with regard to this property; but it is evident there is an error, or at least, a great uncertainty in this estimation, since the celebrated Swedish chemist remarks, that, notwithstanding the greatest purification, this metal contains more than a third of its weight of iron: it therefore appeared to him impossible to determine with exactness, its real specific properties, because, as he observes, the iron must modify them in a certain respect. It is therefore evident, that we ought to attribute the semi-ductility and magnetic property, particularly the polarity, which nickel sometimes exhibits to this metal, namely, the iron. Citizen Guyton gave it the second class for hardness, after manganese and iron, which occupy the first station in this table, and upon the same line as platina; it is very difficult to fuse, and the same chemist places it along with iron. Its dilatibility and conducting power as to caloric, have not been yet determined, neither has it been yet obtained in the crystallized state. Its smell or taste have not been determined, though it is probable, that it possesses peculiarities with regard to both.

### C *Natural History.*

3. THERE are three ores of nickel, very distinct and very easy to be distinguished.

SPECIES

## SPECIES I.

*Sulphuret of Nickel.*

THIS is the most abundant and most easy to distinguish. It has been denominated kupfer-nickel by Hierne, who first described it; it is of a reddish yellow colour, of little brilliancy, resembling tarnished copper, with which its aspect always tends to confound it. Its fracture is rugged, unequal, and its texture fine-grained and close; it easily loses its brilliancy in the air, becomes tarnished, brownish, and at length covered with greenish spots. It forms a vein in the earth. This ore has not been exactly analyzed; it is known, however, that it contains sulphur, nickel, arsenic, cobalt, and iron. The sulphuret of nickel exists in Sweden, in Saxony, in France, &c. It is very far from being as scarce as Bergmann pretended, since it is found in tons at many of the druggists in Paris.

## SPECIES II.

*Ferruginous Nickel.*

I GIVE this name to an ore, which Baronde Born has described in his catalogue of the cabinet

cabinet of Mademoiselle de Raab, under the denomination of nickel alloyed with iron, without arsenic or cobalt, and which he says was found at Joachim in Bohemia. Its texture is foliated, and it is formed of rhomboidal plates applied each other; its recent fracture is of a pale yellow, which becomes black by the contact of the air.

### SPECIES III.

#### *Oxide of Nickel.*

IT is of a bright and agreeable green or greenish colour. It is commonly found at the surface of the sulphuret of nickel, which it sometimes covers entirely, like superficial coating; it is not known either alone or solid, or in any regular form, it is probable, that it contains carbonic acid, from the property which Cronstedt attributes to it. It is this oxide which colours the prase, according to Klaproth's analysis. It is frequently mixed, or, as it were, interrupted by a powder, or efflorescence of a whitish colour. Mr. Kirwan suspects its existence in some species of slate and horn-stone, because these stones colour the nitric acid of a beautiful green.

Besides these three species, Bergmann asserts, that it is not rare to find native nickel, or nickel with very little sulphur, but combined with

iron, cobalt and arsenic, and that it exists, thus mineralized by sulphuric acid. Rinman also affirms, that nickel has been found native in Hesse; it is heavy, of a deep red, forming a kind of product of the furnaces among the materials from which nickel may be extracted. It is considered as an alloy of cobalt and bismuth, by the medium of nickel.

*D. Assays; Metallurgy.*

7. THE ore of nickel is reduced after the manner of Cronstedt, by first roasting it to drive off the sulphur and arsenic; by which treatment it loses one third or half its weight. After this operation, it is found of a green colour, which is deeper the more abundant the nickel: it sometimes is seen during the roasting, when it is left without agitation, that coralliform, hard vegetations are formed, which are sonorous, when struck. The roasted ore is mixed with two parts of black flux, then placed in a crucible covered with muriate of soda, and heated by fusion in a forge-furnace. After the apparatus is cold, a metallic button is found under brown, blackish or blue scoria, which constitutes from the tenth to the half of the original weight.

8. But the first metal thus obtained, notwithstanding the strong action of heat applied to the ore, is very far from being pure; it is still an alloy of nickel with cobalt, arsenic, and particularly iron, and is attracted by the load-stone. It is even from the various proportions of this metal,

metal, that nickel acquires its variety of specific gravity and of grain, either irregular or in plates, and of a colour, which inclines from red to yellow. The metal obtained by Cronstedt in 1750, was very far from being pure; he described it as breaking with large plated fracture, and Bergmann had an opportunity of examining a portion fused by this mineralogist, which was found in the collection made, and left by Swab to the academy of Upsal. The care, the patience, and the sagacity exhibited by Bergmann in his attempts to purify nickel, are unequalled, and nothing can better show at the same time, the almost insurmountable difficulty of obtaining it in a separate state, than the result of his numberless and indefatigable assays made upon the metal extracted by Cronstedt himself. As this is the most essential part of its history, I shall enter into some detail respecting the experiments of Bergmann, in order to show the properties he discovered in this metal in his attempts to purify it. He subjected it to six successive roastings and scorifications, each of which lasted from ten to fourteen hours, and after each scorification, he reduced it with black flux. By this treatment, it emitted vapours of arsenic, and a white vapour which had not the smell of garlic; the powder of charcoal which he added in his operations, facilitated the disengagement of the arsenic: nevertheless, after these six roastings and graduated reductions, the nickel, though much diminished in

P 2 weight,

weight, emitted a smell of arsenic when heated, and it was attracted by the magnet. Bergmann roasted it a seventh time by a violent heat during fourteen hours, adding powder of charcoal, without drawing off any arsenic, or occasioning any loss of its weight. The oxide thus obtained, was of a reddish-yellow colour, with a few traces of the green tinge. By this reduction he obtained, under the scoria which contained no iron, a very small globule which was still attracted by the load-stone.

9. The treatment with sulphur, which appeared to Bergmann to have a great attraction for nickel, and which he hoped might seize that metal, and separate it from the iron, was not, however, attended with greater success than the former process. By fusing the metal obtained by Cronstedt with sulphur, and a small quantity of borax, he obtained a red mass inclining to yellow, which, with eight hundred parts of metal, acquired the weight of seventeen hundred. He scorified half this mass, so as to exhibit the vegetations which the oxide of nickel usually affords; he obtained eight hundred and fifty-two parts of this oxide, which, when fused with the other part which had not been scorified, afforded sulphuret of nickel of a yellowish white, weighing eleven hundred and two; in this case, there were near six hundred parts lost. This sulphuret, after four hours roasting, became covered with vegetations; the addition of charcoal dissipated the arsenic; he obtained an oxide  
of

of a bright green, weighing 1038, which, by reduction, afforded 594 parts of a metal, much attracted by the magnet, very ductile, and very refractory. This metal being fused again with sulphur, one half then scorified and fused with the other sulphurated half, and this whole mass roasted for four hours and again reduced, afforded a metal, red without, of an ash-coloured white within, very brittle, and of which the specific gravity amounted to 7,170. When mineralized a third time, and treated again in the same manner as the two first times by roasting with charcoal-power for twelve hours, till it exhibited no longer any trace of the presence of arsenic, it afforded an oxide of an ash-green colour, from which, by reduction with the most violent fire of a forge, was obtained a metal so refractory that it could not be fused into a button: it was under a scoria, of a hyacinth colour. It weighed 8,66. It was attracted by the magnet; its ductility was so remarkable, that it was extended to the length of  $3\frac{1}{2}$  times its diameter under the hammer; its colour was reddish-blue; it was found to be soluble in a deep green in the nitric acid, and in a blue colour in ammonia. This metal heated to redness for four hours, became covered with a crust of oxide of iron, which being detached by the hammer, a greenish powder was found under it: one hundred parts of this crust being roasted for seven hours with charcoal, exhibited no longer any trace of arsenic, was in-

creased



creased by five parts, and afforded by reduction a metal of the weight of seventy-two parts, of a faint red colour, semi-ductile, entirely attracted by the magnet, and the specific gravity of which amounted to 8,870. It is evident from all those details, that Bergman had succeeded in separating the arsenic, and the cobalt from the nickel, but that he had not insulated the iron, to which we may attribute the ductility of the metal. Thus sulphur has not been of greater utility in refining nickel, than the other scorifications with charcoal, and the multiplied reductions described No. 8.

10. Knowing that the alkaline sulphurets dissolved cobalt better than nickel, Bergmann was led by analogy to believe that these compounds might act in the same manner upon the iron, and consequently serve him to deprive the nickel of it: but his hopes were disappointed. The nickel of Cronstedt, (the reader knows that I apply this name to that which is the product of a first reduction after the first roasting of its ore), already united with sulphur, was fused with more than thirty times its weight of sulphuret of pot-ash; the mass, washed in hot water, afforded by an acid a precipitate, which being roasted till the total separation of the sulphur was effected, was in the state of a cineritious powder weighing more than half of the first metal. The undissolved portion, in which he hoped to find the nickel, being  
equally

equally desulphurated by roasting, became no less cineritious, and gave by reduction a brittle metal, little attracted by the magnet, but which became susceptible of being attracted by it after having been fused with borax. The same experiment being made with the sulphuret of lime, also afforded a ferruginous nickel which adhered very strongly to the sulphur. When nickel was fused with alkaline sulphuret, in another experiment, and at the moment of fusion, nitre was added to it, in a quantity barely sufficient to destroy only a small portion of the sulphuret, this left the metal to be precipitated to the bottom of the vessel: nickel treated in this manner is found to be deprived of cobalt, but still charged with iron. Bergmann observes on this occasion that by the same process the nickel is precipitated by cobalt, which has greater attraction for the sulphuret than the former has, and that being thus separated from its solution in the fused sulphuret by iron, copper, tin, lead, or even cobalt, nickel is not susceptible of being attracted by the magnet; but according to him, it would be a mistake to believe it exempt from iron; as this latter metal, the properties of which are only disguised by foreign substances, and undoubtedly by the sulphur, becomes again magnetic in proportion as we deprive it of them by subsequent means.

11. After

11. After the failure of the preceding means, Bergmann had recourse to nitre, in hopes of scorifying and separating the foreign metals combined with the nickel, which appeared to him to be oxidated with greater difficulty, and to be disoxidated more easily than they. One part of Cronstedt's nickel, being thrown upon twelve parts of fused nitre, emitted some slight sparks; arsenical vapour was soon exhaled; the sides of the crucible were covered with a blue crust of cobalt, and there remained at the bottom a greenish matter. Twelve parts of nitre added to this matter, and fused with it for the space of an hour, still tinged the crucible with a blue colour, and the mass at the bottom became of a brown green colour, much less abundant than the first time. A third addition of nitre in the same quantity left a grey scoria, which gave no metal with the black flux, but merely scoria of a hyacinth colour, spotted with blue, which gave a green tinge to the nitric acid, were converted into a jelly, and left by evaporation a greenish oxide. In a third analogous experiment, the green powder, being lixiviated and treated with half a part of black flux, an eighth of lime, and an eighth of borax, gave a metal of a yellowish-white colour, attracted by the magnet, ductile, and weighing 9,000. Bergmann concluded from this kind of experiment, that nitre was very proper for indicating and separating the smallest portion of cobalt contained in the nickel, but that it left

in it the iron of which it could not deprive it.

12. As muriate of ammonia is known to be very proper for separating iron, Bergmann, tried also this new means; he distilled one part of oxide of nickel, deprived of cobalt sufficiently to give no longer the blue colour to borax, with two parts of sal-ammonia; he obtained a cineritious, white sublimate, accompanied with a little ammonia; the bottom of the retort had assumed the deep hyacinth colour; the residuum consisted of two layers. The upper layer was yellow, scaly, brilliant like massive gold, yielding with borax a glass of a hyacinth colour, without affording metal, attracting the moisture of the atmosphere, becoming green and consistent like butter; being lixiviated, it left a powder having the characters of an oxide of nickel, and the green aqueous solution was rendered blue by ammonia, without affording any indications of iron. The inferior layer consisted of an oxide of nickel, little charged with muriatic acid, blackish, of a ferruginous brown towards the bottom of the vessel. This oxide converted borax into a hyacinth-coloured glass, and afforded by reduction a brittle metal, of a reddish-white colour, scarcely susceptible of being attracted by the magnet. The same metal, treated successively by four other sublimations, with muriate of ammonia, the inferior layer being lixiviated and reduced each time, yielded, at the end, and in the last reduction,

tion, a white brittle metal, little, though still susceptible of being attracted by the magnet. Bergmann observes that each sublimate was very white, and that it afforded not the slightest indication of iron by the tincture of the nut-gall.

13. Bergmann, not discouraged by the failure of all his attempts with processes in the dry way, occupied himself afterwards with the separation of the different metals with which nickel is alloyed, by processes in the humid way. The nitric solution of the nickel of Cronstedt occupied him for a considerable time. By calcining the solid nitrate of nickel with charcoal-powder, much arsenic was disengaged, and he obtained, by the reduction of the residuum, a grey metal, semi-ductile, but still susceptible of being attracted by the magnet; when redissolved in nitric acid, and reduced four successive times, it afforded a metal always magnetic. At the fifth calcination of this nitrate of nickel, its oxide was diminished in such a manner that he found it impracticable to reduce it; which proves that nickel is volatilized in its oxidation by the nitric acid, without its being thereby deprived of its susceptibility of the magnetic attraction.

14. Finally, the celebrated Swedish professor tried, as a last means, the solution of the oxide of nickel in ammonia, in order to separate from it the oxide of iron. After having dissolved some of Cronstedt's nickel in nitric acid, and precipitated its oxide with pot-ash, he treated it with

with ammonia, which dissolved at least a ninth of its weight; this residuum, which was of a black colour, inclining to green, yielded by reduction, a scaly metal, brittle, of a clear white colour, little sensible to the magnet, the specific gravity of which amounted to 9,333; it was easily fusible, by which operation it was again rendered susceptible of being attracted by the magnet, and being dissolved in nitric acid, it yielded a blackish powder, insoluble; evaporable with a smell of sulphur upon the coals. The blue ammoniacal solution, when evaporated to dryness, yielded nearly one half less of residuum than it had taken of matter from the oxide of nickel. This powder afforded, by reduction, a very small quantity of metal, of a whitish colour, semi-ductile, strongly attracted by the magnet, and having a specific gravity of 7000; the scoria of which contained much oxide of nickel, colouring borax with a hyacinth tinge, and affording by its reduction a metal, which being fused with the preceding, became so refractory that it was impossible to treat it. Though the experiments with ammonia did not satisfy the author, they however afforded very singular results; such as the constant solution of the oxide of iron with that of nickel, the blue colour of this solution which, though analogous to that of the oxide of copper, has a very different cast, and especially the loss of a great quantity of oxide of nickel, which Bergmann does not seem to have sufficiently regarded.

In

In a word, the narrative of these last experiments, which show this author to have been fatigued and embarrassed, notwithstanding the zeal and ardour which animated him might lead us to think, as well as that of several of the preceding, either that nickel cannot by any means be purified of iron, or that this singular metal is itself susceptible of being attracted by the magnet, and that in this property it resembles iron, whilst in many others it seems to approach to the nature of copper.

15. After having described in a detailed manner, these different and numerous experiments, as they constitute almost exclusively the exact chemical history of nickel, I ought also to present the reader with the inferences which the illustrious Bergmann deduces from them, in paragraphs XI and XII of his Dissertation. The first 'is, that the sulphur adheres to nickel the least, and the arsenic the most strongly, but that we may separate it completely by roasting with charcoal; that the cobalt remains longer concealed in it, and that we frequently find traces of it when it was not suspected to be present, by means of nitre which separates it in a blue oxide; that the blue cast given to borax is owing to the manganese; and lastly, that iron is of all the metals the most intimately combined with nickel, since it cannot be entirely extracted from it by any known means.

16. As by all the processes of purification, nickel shows to the last the presence of other metallic

tallic substances, several chemists have thought this metal to be nothing more than a natural alloy of arsenic, cobalt, copper and iron. Bergmann discusses, according to his experiments, the question relative to this subject. He shows that we may completely deprive nickel of arsenic; that it hardly ever contains copper; that it differs from cobalt in a great number of its properties; that the more we separate the latter, the more it assumes the properties by which it is distinguished. As to the presence of iron, he agrees that it is more natural to find great analogies between nickel and this metal; he shows in how many properties these two metals approach each other, as well as cobalt and manganese; but he, nevertheless, concludes, that nickel presents too many peculiar properties to be confounded with iron, and that as long as the latter has not been brought into the state of the former, nor their real identity proved, it would be overturning all the foundations of philosophy to build upon vague appearances, and fallacious analogies.

17. He proves, moreover, the truth of this assertion by relating a considerable number of experiments on the alloys of iron and copper, of iron copper and arsenic, of iron copper and cobalt, and of these four metals together in very various proportions; experiments in which he has never been able to obtain a metal similar to nickel. Though some of the properties of these alloys at first presented certain analogies



gies with nickel, he soon found, by a more thorough examination, that this was only a very fallacious appearance; and that there was no real relation between the alloy and the metal which he had attempted to imitate.

No metallurgical works are established upon the ores of nickel, and metallurgists do not yet place any value upon this species of mineral.

#### *E. Oxidability by the Air.*

18. NICKEL is very difficult to be oxidized by the action of caloric and of the air. When it is heated under a muffle, and constantly agitated, it only assumes a dark colour. However, by long exposure to moist and cold air, it becomes covered with an efflorescence of a clear green colour, of a very particular and distinct tinge. It is this efflorescence which is found upon the surface of the sulphureous ores of nickel, the tinge of which being very remarkable, and very different from that of copper, enables us to distinguish them with ease and certainty. This green oxide gives borax a hyacinth colour, and imparts the same tinge to the ammoniacal phosphate of soda, which becomes violet by the action of nitre: a large quantity of this oxide gives this salt a blood-red colour during fusion, which becomes paler by cooling.

#### *F. Union*

*F. Union with Combustible Substances.*

19. **SULPHUR** combines very easily with nickel, and forms an artificial ore which is not altogether similar to its natural ore or Kupfer-nickel. The artificial fulphuret of nickel is hard, yellow, with small brilliant facets. When strongly heated in the air, it emits very luminous and inflamed sparks.

20. Nickel is susceptible of uniting with phosphorous. Pelletier has acquainted us with the phosphoret of nickel; he prepared it either by the reduction of the vitreous phosphoric acid with the addition of charcoal, after having mixed these two substances with the nickel, or by throwing phosphorus upon nickel heated to redness in a crucible. This increased in weight by one fifth, and a small portion of phosphorus was separated from it as it cooled. The phosphuret of nickel is of a more brilliant and purer white than nickel; its texture is needle-formed; when heated before the blow-pipe the phosphorus burns at its surface in proportion as the metal is oxidized. Pelletier has obtained the same result from speiss.

21. Nickel enters into alloys with many metals: it has been seen that it always contains arsenic, often cobalt, and constantly iron. It has been seen, that in the latter alloy, the iron, though fused, is ductile, which has justly been remarked as an extraordinary circumstance by Bergmann. Arseniated nickel gives a blue colour to glass, according to Citizen Monnet.

Bergmann

Bergmann attributes this property to the cobalt, which the arsenic separates from the nickel.

*G. Action upon Water and the Oxides.*

22. It would be natural enough to imagine that nickel, which has so much analogy with iron, should exert an action upon water; but there is no experiment which proves this to be the fact, or which even authorizes us to suppose it.

23. We may assert that nickel exerts no action upon the metallic oxides, as most of the metals have, on the contrary, the property of precipitating nickel from its solutions, as will soon be shown.

*H. Action upon the Acids.*

24. ALL the acids act upon nickel or its oxides. All the combinations of this metal are constantly green, and of a clear and very brilliant colour, which is very remarkable and very different from the green afforded by certain metals. This is one of the richest and most beautiful colours that can be exhibited. The fixed alkalis precipitate all these solutions in a greenish white, and communicate a yellow colour to the oxide which they re-dissolve.

25. The sulphuric acid, concentrated, and distilled upon this metal, is decomposed; sulphureous gas is disengaged, and a grey mass remains, which dissolves in water, and immediately communicates to it its beautiful green colour. By evaporating this solution we obtain

foliated crystals, of the colour of a pale emerald. I have seen crystals of sulphate of nickel prepared by the ingenious processes of Citizen Leblanc, in beautiful square prisms, very thick and long, of a rich deep-green colour, terminated by summits obliquely truncated. The sulphuric acid also dissolves the oxide of nickel with facility. Bergmann says that this salt forms itself in decahedrons, or yields compressed aluminiform crystals, with truncatures at the two opposite summits.

26. The nitric acid oxides and dissolves nickel with the aid of heat; it effects, without effervescence, the solution of the oxide of this metal; it is of a green colour, and gives deliquescent rhomboidal crystals, which are decomposed by the action of fire, and leave, by strong calcination, a blackish oxide, after having yielded oxygen gas. Exposed to dry and hot air, the nitrate of nickel loses its water of crystallization, and even its acid, so as to leave a greenish oxide, in which we frequently find a small quantity of iron and of arsenic.

27. The muriatic acid dissolves nickel and its oxide more slowly than the nitric acid: this solution, which is green and brilliant, affords irregular and undetermined crystals. The muriate of nickel is decomposable by the action of fire, and even of the air in the course of time. The action of the oxygenated muriatic acid upon this metal has not yet been tried.

Vol. V.

Q

28. The

28. The other acids exert only a feeble and slow action upon nickel. The fluoric acid charges itself with difficulty with its oxide, and gives crystals of a clear green colour. The phosphoric acid has only a feeble attraction for this oxide; this solution has scarcely the slightest greenish tinge, and affords no crystals. The boracic acid does not unite with it unless by double elective attraction. The liquid carbonic acid, left for a long time in contact with nickel, afforded Bergmann no certain sign of its solution. The arsenic acid forms with nickel a green saline mass, which is obtained by double attractions; it separates from the nickel a saline and little soluble powder. The action of the tungstic, molybdic, and chromic acids upon nickel is not known.

#### *I. Action upon the Bases and the Salts.*

29. THE arid earths, flux, alumine, exert no action upon nickel; treated by alkaline fluxes, with its oxide, they become tinged with a hyacinth, or an orange-red colour; if it contain much arsenic, or cobalt, the glasses which it tinges turn to the blue or violet colour.

30. The fixed alkalis dissolve its oxide in little abundance, and assume with it a yellow colour; but this oxide is very soluble in ammonia, which does not act upon the metal. The ammoniacal solution is of a deep blue colour, which has not the liveliness and lustre  
of

of that of copper, concerning which we shall speak hereafter ; it has its characteristic tinge, which an experienced chemist ought easily to recognise. When evaporated, it precipitates a blackish-brown powder, and passes from the blue to the green colour. Most of the metals separate the nickel from it. This great solubility of the oxide of nickel in ammonia serves sometimes to separate it from that of cobalt.

31. Nickel acts, amongst the salts, only upon the genera of the nitrates, the super-oxygenated muriates, the phosphates and the borates. The two first burn it and reduce it to the state of oxide ; it fuses with the two others, combines with them, and gives them a hyacinth colour. It may be remembered that the nitrate of pot-ash, which detonates feebly with nickel, enables us to find in it, by blue scoria, cobalt, of which no other means can show any trace. The super-oxygenated muriate of mercury burns this metal in a still more lively and complete manner, and may serve to purify it, as also to make the analysis of its ores, when the use of this important salt shall be better known, and more generally diffused than has hitherto been the case. These two saline substances cause the hyacinth colour of the oxide of nickel to re-appear, or augment it with much intensity in glasses, which, on account of the small quantity which they contain of it, and even on account of their vitrification itself, present no trace of it, or exhibit only a very slight tinge.

K. *Uses.*

32. NICKEL has hitherto been applied to little or no use: it cannot, however, be doubted, that it may be employed with great advantage in the manufacture of enamels, glass, porcelain, and pottery. It is even probable, that it may be an ingredient in the secret processes of some manufactures, as large provisions of it are frequently found with the druggists of Paris, who procure it from Saxony only in proportion to the demand which is made for it.

33. When new investigations shall have been made relative to this singular metal, which deserves all the attention of chemists; when the means of purifying it shall have been discovered, which I believe to be more easy than Bergmann thinks, it will become very advantageous, and undoubtedly much employed. Hitherto, it has been only a species of alloy for chemists. If after its purification, it exhibits the considerable ductility of which Bergmann has spoken, it will be necessary to remove it from the rank which I have assigned it in the System of Chemistry, and place it immediately beside zinc. I have not yet placed it in this rank, but have left it after cobalt, because, with some analogies with this metal, it appeared to me, that it must owe its ductility to its being alloyed with iron.

## ARTICLE X.

*Of Manganese.**A. History.*

1. THE native oxide of this metal has long been employed in the glass manufactories, under the name of *glass-maker's soap*, on account of its property of whitening glass; it was known by the name of *black magnesha* or manganese. Its multiplied uses had given no light respecting its intimate nature, and before the exact investigations of which I am about to speak, no less erroneous, than different opinions concerning it, had obtained amongst mineralogists. Most naturalists considered this substance as a poor and refractory iron ore, undoubtedly, on account of its colour, and the ferruginous oxide with which its surface is often covered, or with which its fragments are frequently accompanied in the mines. However, Pott and Cronstedt, the first mineralogists who have drawn great lights from chemical analyses for the knowledge and classification of fossils, did not recognise in their experiments the ferruginous nature of the substance which was called manganese. Other mineralogists had placed this metallic fossil amongst the ores of zinc, without having given any proof of this hazarded assertion. Westfeld  
pub-



published, in 1767, a treatise upon this mineral, in which he endeavoured to ascertain its constituent parts, but by experiments so inaccurate, that his work is a series of errors, to which, indeed, the period in which he wrote greatly contributed.

Bergmann and Scheele are the first chemists who, having chosen manganese for the object of their investigations, have placed its nature as a particular metal in the clearest light. The former has given its history in his excellent Dissertation on the white ores of iron, in 1774, and had already, for some years, considered it as a metal different from all others, on account of its weight, its property of colouring glass, that of being precipitated in a white form by the alkaline prussiates, and on account of the impossibility of either separating from it several different metals, or of imitating or producing it by alloys. Scheele, induced by Bergmann, who showed all the importance of such an inquiry, to examine with accuracy the native oxide of manganese, laid before the Academy of Stockholm, in 1774, after researches continued during three years, a memoir which deserves to be considered as a masterpiece of this able chemist, though he has deceived himself with respect to the theory of the phenomena which this substance presented to him. His work contains a numerous series of discoveries, which led him to consider this fossil as the oxide of a particular metal, very different

different from all others. It was in the course of his labours upon this native metallic oxide that he discovered its properties, and the particular nature of barites.

3. Gahn, a pupil of Bergmann, was the first who, according to the testimony of his master, obtained the particular metal contained in the native oxide of manganese, and since him, almost all chemists have succeeded in extracting it. Mr. Champy was one of the first who extracted it in considerable abundance in France, from the oxide of manganese of la Romèneche, and obtained it in the form of a well-formed button. Mr. Isleman has published, in Crell's Journal, a series of experiments upon this metal. M. M. Engestroom and Rinman have given, in the Memoirs of the Academy of Stockholm, details concerning several ores of manganese, and have confirmed all the results of Scheele. Citizen Lapeyrouse has given accounts of a great number of varieties of ores of manganese, and has especially discovered this metal in its native state in France.

4. The French chemists, since the establishment of the pneumatic doctrine, have given a new value to the experiments of Scheele and Bergmann, either by rendering them subservient to the consolidation of this doctrine, by the fundamental principles of which they are explained, at the same time in so natural and so simple a manner, or by pointing out a relation between them, of which their authors had not

been aware. They have shown, that no substance presents more favourable phenomena than this new metal to the data of the theory of the elastic fluids, and they have found in manganese, and especially in its oxide, a source of processes and experiments which would alone be sufficient for establishing all the fundamental points of this doctrine. The analogy of these phenomena with those presented by other metals, and the combustible bodies in general, especially produce the strongest conviction in the minds of those who observe them. On this account, I shall expose them with every requisite elucidation, offering them, particularly as a striking picture of the collective bases of the French pneumatic theory,

#### *B. Physical Properties.*

5. MANGANESE extracted by the process that shall be indicated, is distinguished from all other metals by the following properties. It is of a brilliant whiteness approaching to grey, which is quickly altered in the air; its texture is granulated, without being so fine and close as that of cobalt; its fracture is rough and unequal; its specific weight is 6,850. It holds, together with iron, the first rank in the order of hardness. It is one of the most brittle metals: at the same time it is one of the most difficult to be fused. Citizen Guyton places it immediately after platina, and determines it at the

160th

160th degree of Wedgwood's pyrometer. We know neither its dilatability by caloric, nor its conducting property. It is frequently susceptible of being attracted by the load-stone, especially when it is in the state of powder, on account of the iron which it contains, and which is almost as difficult to be separated from it as from nickel; it has no perceptible smell nor taste; in communication with other metals, it exerts the galvanic action upon the nervous and muscular systems of animals: its colour is extremely variable.

*C. Natural History.*

6. ONLY one ore of manganese is as yet well known, namely, its native oxide, which some modern mineralogists, amongst others Mr. Kirwan, announced as being combined with carbonic acid. This oxide is frequently mixed with iron, barites, flint, lime, &c.: it varies also by its state of oxidation, or by the proportion of oxygen which it contains. The following are the results which Scheele has obtained respecting its varieties of colour. The blue oxide is the least oxygenated of all: the green proceeds from the mixture of the preceding with the yellow oxide of iron; in the yellow, the latter is very predominant: the red is more oxidized than the preceding ones; the black, on the contrary, is oxygenated in the highest possible degree.

7. Mr.

7. Mr. Kirwan distinguishes three principal varieties of native oxide of manganese, the white, the red, and the black.

A. The white, which contains the least iron and the least oxygen: M. Rinman has found it in small crystals, or in rounded masses of a sparry texture in the cavities of quartz; he has found some of a yellow colour, covered with a blackish and fuliginous incrustation. Citizen Lapeyrouse has found it in a spongy efflorescence upon ores of iron, and especially upon the hæmatite. There are carbonates of iron, of a white colour, which contain more of this oxide than that of iron. Every white oxide of manganese becomes tarnished in the air, and powerfully absorbs oxygen from it.

B. The red, according to Mr. Kirwan, contains less carbonic acid, and more iron than the white; it is, either friable, or hard in carbonate of lime, schistus, upon the hæmatites, or in lamellated masses, radiated or crystallized in pyramids, in rhomboids, in short and brittle needles.

C. The black and brown frequently crystallized like the red, or in solid masses of a metallic or a tarnished and earthy appearance, mixed with quartz, &c.; it weighs 4,000. To this variety, Mr. Kirwan refers, 1. *The Perigord stone*, generally of an obscure grey colour, very heavy, easy to be scraped with the knife, though hard and difficult to be broken in pieces, becoming harder, and of a reddish-brown colour  
by

by calcination, without becoming attracted by the magnet, giving borax the colour of the amethyst; 2. *Black-wad*, of a deep brown colour, in the form of powder, or small, hard, and brittle masses, in which Wedgwood has found 0,43 of manganese, 43 of iron, 0,14 of lead, and 0,05 of mica, and which, after having been dried, and kneaded cold with lintseed-oil, becomes spontaneously heated and inflamed.

8. Citizen Haüy, who gives only one species of ore of manganese, its native oxide, divides its varieties into two sections; the one possessing the metallic state, at least, in the fracture, and easily transmitting the electric spark; the others destitute of the metallic state, and transmitting the electric spark only in a feeble manner.

The first have some resemblance with the native sulphuret of antimony: the distinguishing character, which is easily recognised, is that the oxide of manganese, rubbed upon a dark-coloured stone like the slate, and wiped lightly with the finger, leaves a tarnished and dull-coloured trace, whilst the sulphuret of antimony marks it with a very sensible metallic brilliancy.

The second varieties are of different colours, especially black, brown, yellowish, red, of different prismatic forms by diminution, solid and compact, tuberculated, in efflorescence. They yield oxygen gas, like the first, and frequently more than those, when heated in close-vessels.

9. When we compare the different forms and appearances presented by the numerous varieties

ties of native oxide of manganese, we find that the most regular, and at the same time the most brilliant and metalliform, is in tetrahedral rhomboidal prisms, striated and separate, or in needles united into bundles, or in rays and stars. Amongst those which have not the metallic appearance, we particularly distinguish a brown, blackish, and friable efflorescence, which stains the fingers like soot; a variety of a dull velvet black; the compact and irregular grey variety, reddish-brown, compact, very heavy, cavernous, exhibiting rudiments of shining crystals in its cavities: the latter is frequently called stone, and it is the most common and most in use in the manufactories of glass.

10. Citizen Lapeyrouse discovered and described, in the year 1786, native manganese in metallic globules at Sem, in the iron-ores of the valley of Vicdefos, in the [ci-devant] comté de Foix. He is the only naturalist who has found this metal in the native state. It was in the form of small buttons a little flattened, malleable, of a lamellated texture: it is very probable, that this was only an alloy with iron; for manganese is too combustible to be capable of remaining without alteration in the metallic form.

11. It is necessary to add, that the oxide of manganese is found very frequently with other mineralized substances, especially in the ores of iron, that Scheele has found it in a great number of charcoals and vegetable ashes, and that  
he

he attributes to it the green and red colours, which the fixed alkali that proceeds from these ashes so often assumes. We shall have occasion to speak again of this phenomenon in another place. Hielm has found the muriate of manganese dissolved in waters near the lake Wetteren; and Citizen Guyton assures us, that carbonate of manganese exists in the water of the coast of Châtillon in Bugey.

*D. Assays and Metallurgy.*

12. THE native oxide of manganese is not well reduced, except when we avoid heating it with fluxes, and this is undoubtedly the reason why the chemists have remained so long ignorant of the existence of the particular metal which is contained in it. Gahn first succeeded in obtaining it, only because he employed no flux; in however small a quantity we may add these, the oxide becomes vitrified: this fact has since been well confirmed by Bergmann, by Citizens Guyton and Champy, and by my own experiments. According to these principles, the following is the process of Bergmann, which succeeds well.

13. We form a paste of native oxide of manganese finely pulverized, and water; of this we form a ball, which we place in a lined crucible, upon the bottom of which is beaten a thick layer of powdered charcoal; we surround and cover the ball with charcoal; and close with another



other crucible inverted and luted; and then heat with the most violent fire that can be made in a laboratory for upwards of an hour. It is necessary that the temperature of the furnace should amount at least to 160 degrees of Wedgwood's pyrometer. After the crucible has cooled, we find below, or even in the middle of a scoria, more or less vitrified, one or more metallic globules, which amount to near a third part of the quantity of the oxide of manganese that has been employed; Bergmann makes them amount to 0,30. If the fire be not sufficiently strong, the grains of metal being too small and disseminated in the scoria, cannot unite. It is also observed, that when the crucible is overheated, and the metal touches its sides, the whole mass is vitrified, and no metal is obtained. I have several times attempted this difficult reduction: I have never had a sufficiently strong fire in my laboratories to collect the manganese in a single button; but I have obtained it in grains or small globules, each of which were surrounded with a vitreous crust of a deep green colour.

14. Bergmann, in his Dissertation on humid Assaying, gives as docimastic processes for the ores of manganese, the solution in nitric acid, with the addition of sugar, evaporation to dryness of the nitrate which is thus obtained from them, and treatment of the mixed oxides of manganese and of iron, by the acetous, or the very weak nitric acid, which dissolve the first, without attacking the second by  
the

the addition of the sugar. He observes also, that when a solution of manganese and of iron is precipitated by the alkaline prussiates, the precipitate of prussiate of manganese is soluble in water, whilst that of iron is not, and that this property furnishes a very good means for separating these two metals. It was by this means that Citizen Guyton discovered the presence of carbonate of manganese in the water of Châtillon; but he remarks, that there is at the same time a small quantity of prussiate of iron dissolved in it.

15. The ores of manganese are not worked in the large way, not merely on account of the refractory nature of these ores, but more especially because it is of no utility in its metallic state. The places where the native oxide of manganese is found, are merely worked, in order to furnish the manufactories of glass, &c. with this oxide which is employed in them.

#### *E. Treatment by Fire and Air.*

16. It must have appeared from the preceding details, that as the oxide of manganese exists in great abundance in the bowels of the earth, whilst the metal, on the contrary, is very difficult to be obtained, the oxide only must have been employed in the arts. As it is also upon this substance that all the experiments and discoveries of Scheele have been made, who did not know the metal, there is no other method whereby  
we

we can well understand and comprehend the whole, than to compare, in the exposition of each mode of treatment and phenomenon, the properties of this metal and those of the oxide, or rather of the oxides; for it will frequently be necessary to describe, in particular the effects of that which is at the *maximum*, and that which is at the *minimum* of oxidation.

17. There is no metal equally combustible, and which combines with oxygen more easily as well as more speedily, than manganese. Bergmann had remarked, that its colour was very subject to alteration by the air, and that it was sometimes resolved into a brown powder approaching to a black, which weighed more than the entire metal; he was still ignorant of the cause of this phenomenon, which he attributed in a vague manner to the little approximation of the particles; moisture had appeared to him to favour it, as well as the impression of the atmospherical air; for he had observed, that a small fragment of this metal, inclosed in a dry well-corked bottle, remained entire for the space of six months, but that having been afterwards exposed to the free air for twice twenty-four hours, its surface was tarnished, and it had become friable under the finger; finally he observed, that the parts most charged with iron resisted this spontaneous alteration much better. This is, undoubtedly, the case with the buttons that were kept exposed to the air for several years without alteration by Citizen Guyton, though,

though, they were, however, not sensibly magnetic. The following is what I have ascertained relative to the spontaneous oxidability of manganese. On breaking the small globules, which I had obtained by the reduction of the native oxide without flux, I perceived that their fresh surface, from the brilliant greyish white which it exhibited at the moment when it was first exposed, became almost instantaneously tarnished in the air, and soon assumed a lilac colour, afterwards a violet, which quickly passed into a black. In the latter state, they were friable under the finger, and formed a black powder similar to the native oxides. Having inclosed some of these globules entire, and covered with the small layer of oxide formed or left during their fusion, in a small bottle well-corked, they remained there entire; but having broken them, in order to observe their grain and internal texture, and having placed them again in the same bottle, which was agitated from time to time in order to observe them, they were found at the end of some months entirely reduced to a black powder, which was more ponderous than the globules had been.

18. It cannot be doubted that this phenomenon depends upon the quick and easy absorption of the atmospheric oxygen by the manganese; but it is very remarkable, that this is the only metal which presents so rapid and violent an absorption. This celerity of combustion,

which is not surpassed by any of the combustible substances except phosphorus, is united with the powerful attraction which this metal exerts upon oxygen. We shall see hereafter that it takes it away from iron and zinc, and that it ranks above all other metals with respect to this property: accordingly Citizen Guyton has placed it in the first rank of oxidability; but it is not evident with what reason he places in the same line, iron, zinc, cobalt, and nickel, as these metals are far from exerting upon oxygen an equally strong and active attraction. This is incontrovertibly proved by one of the experiments of Bergmann. Having strongly heated, for the space of twenty minutes, with the acid of sulphur, some pieces of manganese inclosed in a covered Hessian crucible, in which, however, there was a sufficient quantity of air to effect its oxidation, he obtained an opaque yellow glass, and a small globule of iron; consequently the manganese was oxidated and vitrified in a place and temperature in which the iron resisted and was merely fused. This remarkable oxidability of manganese has induced me to think that it might be employed as an eudiometer, and that in order to preserve it, it ought to be kept under oil, as water is not adequate for this purpose.

19. It is natural to expect that manganese must be still more altered and burn with rapidity when heated in contact with the air. We see it pass successively through the grey, yellow, red, brown,

brown, and black colours, in proportion as it absorbs larger quantities of oxygen. Bergmann says, that the artificial oxide, heated for twelve days, without interruption, passes to an opaque green colour. I have no doubt, that at a high temperature, to which it should be raised with rapidity and without having suffered it to saturate itself with oxygen, for example, when heated to redness in a well-closed apparatus, and suddenly plunged into vital air, at the moment when it would be ready for fusion, it would become inflamed in as lively a manner as iron and phosphorus, and throw out burning and very luminous sparks to a considerable distance, though the experiment has not yet been made. The proportions of oxygen have not yet been determined, which it contains in its different states of oxidation, from the grey-white, its evident *minimum*, to the deep black, its certain *maximum* of oxidation. Bergmann asserts, that manganese that had effloresced in the air, and been converted into an obscure (brown) oxide, during fourteen days, was augmented by 0,35. It is known, that at the ultimate term of oxidation, an hundred parts of manganese are increased in weight to 168.

20. The native or artificial oxides of manganese comport themselves differently, when we expose them to the light and the action of caloric, according to their state of oxidation. Those which are the most oxidized and the blackest, to which those which are brilliant and

metalli-form in nature sometimes approach, when distilled, or rather heated, in close vessels, with the pneumatico-chemical apparatus, yield large quantities of considerably pure oxygen; less is obtained from the clear brown, the yellow, and the grey, and none at all from the white oxides. This fact, which is well attested, proves that the different portions of oxygen contained in the most complete oxide of manganese, adhere to the metal with a different force, and that we may separate from it more or less easily the portion which blackens it, and in general colours it beyond the white, and that that which is combined with it in the last-mentioned state of colouration, adheres to it with such energy, that the action of the fire is incapable of separating it without the intervention of a substance which joins to it its own particular attraction, such as charcoal.

21. This property of the coloured oxides of manganese, of affording oxygen gas by the action of caloric, is frequently made use of in the chemical laboratories for procuring this species of elastic fluid. It has, however, been observed, that this gas is not so pure as that which is extracted from the spontaneous oxide of mercury, and especially as that which is afforded by the super-oxygenated muriate of potash. Sometimes it contains a small quantity of carbonic acid gas; sometimes also we find in it a small portion of azotic gas, and it is undoubtedly to the presence of the latter substance, that

we are to attribute the singular fact, observed long since by Bergmann, of some nitrous drops or vapours disengaged during the treatment of the oxide of manganese, in a distilling apparatus. It is therefore evident, that for accurate experiments, the gas disengaged from the super-oxygenated muriate of pot-ash is to be preferred.

22. In proportion as the oxygen is separated in the form of gas from an oxide of manganese coloured by the action of fire, it loses its colour, and always passes towards the grey or white, which as we have already seen, approaches to the metallic state : when this oxide, in part dis-oxidized, is exposed to the contact of the air, it absorbs atmospherical oxygen, blackens, and becomes capable of yielding a new quantity of gas by the action of caloric. I have repeated this experiment three successive times upon the same oxide of manganese, and have thereby convinced myself that this oxide, deprived of the portion of the oxidating principle, which is disengaged from it by the action of caloric, is a species of load-stone (*aimant*) for the atmospherical oxygen, by the aid of which we may procure this gas, almost without any other cost than that of the combustibles requisite for disengaging it; but this gas is not sufficiently pure for delicate experiments.

23. To these properties of the oxide of manganese dependent upon caloric, there is also to be added that of vitrifying alone when acted



upon by a strong heat, and of yielding a greenish glass when heated in a vessel which contains air, and which does not suffer the oxygen belonging to the metal to be disengaged in the state of gas.

*F. Treatment with combustible Bodies.*

24. No combination is known of manganese with azote, hydrogen, and carbon. It is known, that the latter, heated strongly with the oxide of this metal, takes from it its oxygen, and reduces it if at a very high temperature: it appears, that it does not unite in this case with the metal, but with the iron which is alloyed with it, as will be shown hereafter.

25. Bergmann says, that metallic manganese appears to resist combination with sulphur, which I do not yet consider as certain; but he describes the combination which he formed between sulphur and the oxide of manganese. Eight parts of this oxide united with three parts of sulphur, in a glass retort, and produced a greenish yellow mass, susceptible of being attacked with effervescence, and yielding sulphurated hydrogen gas by the acids. Scheele has also observed that part of the sulphur passed to the state of sulphureous acid in this operation.

26. Pelletier has spoken of the combination of manganese with phosphorus. Having heated equal parts of phosphoric glass and manganese

with a quantity of charcoal, equal to an eighth of the former, he obtained a phosphuret of a white, brilliant, and metallic colour, of a granulated texture, much disposed, as he says, to crystallization, brittle, and which remains in the air without efflorescence. He observes, that the manganese which he employed was not efflorescent in the air. It is known, that this property depends upon its being alloyed with iron. Above the phosphuret of manganese, there was an opaque glass of a yellowish colour. He effected the same combination by throwing phosphorus upon manganese heated to redness in a crucible. This latter experiment having been made with efflorescent manganese, Pelletier observes, that the phosphuret, which was obtained, does not possess that character. This phosphuret seemed to him to be more fusible than manganese: when it is fused with the blow-pipe, the phosphorus is seen to burn in proportion as the metal is oxidized.

27. Manganese fuses and forms alloys with most of the metallic substances; however, its alloys have hitherto been but little examined, especially those formed with the metals that have already been described.

#### *G. Action upon Water and the Oxides.*

28. THOUGH the labours of Bergmann and Scheele upon manganese and its oxide have not been resumed since the discovery of the decomposition

position of water, and though experience has not yet decided upon the reciprocal effects of this metal and that liquid, yet the celerity with which the metal unites with oxygen, and the attraction which it appears to have for the first portion, which converts it into white oxide, renders it probable to me, that it is, like iron and zinc, and perhaps even still more than these two metals, capable of decomposing water, and depriving it of its oxygen. We shall soon learn some facts, which appear to prove it in a sufficiently demonstrative manner; and it is on this account that I have advised not to keep it under water.

29. Its strong attraction for oxygen indicates, that it is capable of taking this principle from most of the metallic oxides, and this is in fact what happens when we plunge it into solutions of these oxides by the acids; but it is necessary we should attend to the different attractions which it has for various proportions of this principle, and to be well aware, that in heating its black oxide, or that which is most oxidated, with certain metallic substances, it may relinquish to them the part of its oxygen to which it adheres the least, and thus contradict in appearance the general difoxidating property, which ought to constitute its specific character. This variety of attraction for different proportions of oxygen produces much variation in its properties, and gives rise, as I shall show hereafter, to a number of phenomena, which sometimes seem to be contradictory to each other.

H. Treat.

*H. Treatment by the Acids.*

30. IT is in this reciprocal action of manganese and its oxides, that the most singular facts in its history, and the most numerous phenomena of its combinations consist. It is upon this action that Scheele and Bergmann have mostly insisted. Whilst it served them to support the singular theory which they had already adopted concerning heat, as composed of air and *phlogiston*, it furnished the pneumatic doctrine with the most happy results for its proofs, and the most substantial support for its confirmation, as I shall show in the details upon which I am about to enter, as well from the experiments of the two illustrious Swedish chemists, and those which are peculiar to myself.

31. The concentrated sulphuric acid acts even in the cold upon manganese; its action is much more prompt and stronger when it is diluted with two or three parts water. Whilst it takes place, a remarkable quantity of hydrogen gas is disengaged; but its solution is much slower than that of iron. There remains in the liquor a black spongy mass, which retains the form of the metal, and which, as Mr. Kirwan has shown, is carburet of iron, a proof of which I have advanced (No. 24), that carbon, in the reduction of the manganese, combines with the iron. Its neutral solution is white and colourless; it affords  
by

by evaporation transparent crystals, which are also colourless, in the form of parallelipipeds, of a very bitter taste, which first decomposes, disengaging from them sulphuric acid and oxygen gas, and from which the fixed alkalis separate a white oxide which quickly becomes brown when exposed to the air, beginning at the uppermost layer in the vessel in which the precipitation has been made; but the alkaline carbonates precipitate from it a carbonate of manganese which does not absorb the atmospheric oxygen, nor become black like the preceding. In this action of the sulphuric acid we see the decomposition of water, and the fixation of a certain proportion of its oxygen which does not amount to more than 0,20, in the manganese, the white oxide of which is dissolved in proportion as it is formed in the sulphuric acid. The white oxide of manganese, separated by the pure alkalis, dissolves in all the acids when it is not yet become black, and at the moment when it has been precipitated, without having been exposed to the air, and without having absorbed oxygen, which renders it insoluble. It is on account of this solubility that the white oxide quickly disappears in the sulphuric acid, even though it be diluted; and as it contains exactly the quantity of oxygen requisite for its solution in this acid, it combines with it, without requiring to absorb any from it, and consequently without effervescence. For this effect takes place during the combination of the metallic manganese,

manganese, only because it absorbs the oxygen of the water, from which it at the same time disengages the hydrogen.

32. The black oxide of manganese is dissolved with difficulty, by degrees, and in small quantity, in boiling sulphuric acid; however, the saturation of the solution is at length effected; and we find the cause of both these effects, on the one hand in the slowness of the solution, and on the other in the saturation which is effected. When we perform the operation in a close apparatus provided with a pneumatic apparatus, we obtain oxygen gas, which manifestly proceeds from the oxide of manganese, which being thus disoxidated, becomes soluble in the sulphuric acid. If we distil to dryness, and wash the residue, this fluid takes up sulphate of manganese; and when the same operation is repeated several successive times, the whole of the oxide of manganese is taken up. It is very evident in this case that the sulphuric acid, by its attraction for the oxide, taken at its *minimum*, or in its white state, is the cause of the disengagement of oxygen, since this disengagement is rendered much more speedy by this addition of acid than it is in the distillation of the oxide alone, as is well known by all chemists who have occasion to procure this gas. Another fact, which we owe to Scheele, equally proves the influence of the hot sulphuric acid in the disoxidation of manganese; namely, that if we add sugar, honey, or gum

gum to the mixture of sulphuric acid and this oxide, we render the latter soluble without its disengaging oxygen in the form of gas, since it is absorbed by the vegetable matter; an absorption which does not take place without the presence of the acid, for it is in vain to mix the oxide with the vegetable substances alone, they do not in any manner affect the oxidation. In the case of this addition, we see why the solution in the acid is more prompt than when it acts alone. In fact, there are here two forces which conspire together, that of the acid upon the disoxidable oxide, and that of the vegetable matters upon its oxygen: some metals, even gold, according to Bergmann, act by the same principle, and favour the solution of the black oxide in sulphuric acid.

33. When, in the combination of the black oxide of manganese with sulphuric acid, which I have just described, we distil to dryness this acid slightly diluted upon half its weight of oxide, we extract more than a fourth of the oxide, dissolved in sulphate, by means of water; and the solution is red or violet, as well as the crystallized salt which is obtained from it; which shows that in this case the oxide of manganese retains more oxygen than when the solution is white, as it is when the metal itself is made to act upon the acid; it is also to be concluded from hence, that there are two sulphates of manganese, the one little oxidated, which is the white; the other at the maximum of oxidation in which the acid

can suspend this oxide. We shall see that the case is the same with iron, which also affords two different sulphates, according to the state of oxidation of the metal. We quickly obtain the red or violet sulphate of manganese, and particularly the latter, by uniting with the sulphuric acid the oxide of this metal formed by its exposure to the air, an oxide which easily dissolves in it. The alkalis precipitate it in a reddish state, and this precipitate blackens very quickly in the air. Bergmann observes, on this occasion, that the red oxide of manganese holds in this respect the middle rank between the black and the white, that it is more soluble in the sulphuric acid than the first, and less so than the white; we must add, that it forms with it an oxygenated or coloured sulphate, whilst the white affords a simple and colourless sulphate. Vegetable substances that possess avidity for oxygen, destroy the colour of the oxygenated sulphate of manganese, decompose it, and cause it to pass into the white state or that of simple sulphate. It appears, according to several observations of Scheele, that organic bodies in thus disoxidating the manganese, and favouring its solution in the acids, operate by means of their carbon, since he has remarked that carbonic acid was disengaged.

34. The sulphureous acid acts but feebly, or not at all, upon manganese, though it exerts a considerable action upon its oxide. Scheele had observed, that on receiving sulphureous acid into  
water,



water, in which black oxide of manganese has been infused, this grows white, disappears, and is gradually dissolved in this liquid acid, without either motion or formation of bubbles. Moreover, he had remarked that this solution was of the sulphate, not of the sulphite of manganese, and that this sulphate was white. Nothing can be more clear than this phenomenon in the pneumatic doctrine. The sulphureous acid, having great avidity for oxygen, takes it away from the highly oxidated oxide, and returns to the state of sulphuric acid, which speedily dissolves the oxide, deprived of the portion of oxygen which was the cause of its insolubility. Hence it is evident that no effervescence can take place, and that the solution must contain white and simple sulphate of manganese. All these details will serve to place the action of the other acids upon manganese and its oxides in a clearer and more simple point of view.

35. Nitric acid dissolves manganese with effervescence and disengagement of nitrous gas; there remains behind a spongy, black, and light mass of carburet of iron, which is not soluble. This solution is coloured on account of the iron which it contains; its colour is dark, and there is no red or violet nitrate of manganese, as there is sulphate. The white or least oxidated oxide of manganese dissolves very easily in the nitric acid, and without effervescence as well as without disengagement of nitrous gas: this is owing to the circumstance, that  
the

the oxide containing the portion of oxygen which it can hold in order to remain united with the acids, does not require to take any from the nitric, and consequently to decompose this acid as its metal does. This nitric solution of the white oxide is colourless, as long as it contains no iron; it affords no crystallized nitrate of manganese, not even by slow evaporation. The black oxide dissolves only in very small quantity, and with great difficulty in the nitric acid, but it may be saturated with it in course of time. It is evident that this difference between the nitric and sulphuric acids depends upon its being more volatile, its not having so great an attraction in general for the metallic oxides, its always tending more to yield oxygen to them, than to deprive them of it: the addition of sugars of honey, of oils, and even of metals, to the mixture of the black oxide of manganese and the nitric acid, favours their combination; and the oxide, deprived of a portion of its oxygen by these bodies, whose tendency to unite with it is increased by the acid, dissolves in this acid. Carbonic acid gas is disengaged in this operation, and more even than in that which is performed with the other acids.

36. The nitrous acid dissolves the oxide of manganese much better than the nitric. Scheele has seen and well described the important phenomena of this solution: it takes place without effervescence. Nitrate, not nitrite, of manganese is formed; the sulphuric acid afterwards disengages

disengages white, not red vapours from it. This manifestly proceeds from the absorption of the oxygen by the nitrous oxide, as is proved both by the solution of the oxide, which cannot take place without its previous disoxidation, and by the conversion of the nitrous into nitric acid. It is superfluous to remark in this place, how well all these facts accord with the pneumatic doctrine, and give stability to the principles which constitute it.

37. Manganese dissolves with effervescence, and disengagement of hydrogen gas in the liquid muriatic acid. Its white oxide unites with it also, but without effervescence or separation of gas, as it does not require any absorption of oxygen, with which it is sufficiently provided to dissolve in this acid. Its black oxide also dissolves in it more easy than in the preceding acids, on account of the two-fold tendency which this acid exerts, on the one hand upon the oxygen with which it in part becomes saturated, in order to pass into the state of oxygenated muriatic acid; and on the other, upon the oxide of manganese, at the *minimum* of oxidation, with which it forms a salt. When we cause the muriatic acid to act upon the black oxide of manganese, there are two remarkable actions of this acid, and it divides its energy into two forces which form an equilibrium between themselves, or rather which do not cease to act till they are in equilibrio: the one disoxidates the manganese, and forms oxygenated muriatic acid  
till

till it has become soluble; the other dissolves it and causes a portion of the acid to enter into a saline combination. This experiment led Scheele to the discovery of the acid which he termed *dephlogisticated marine acid*, and the French chemists to the knowledge of the real nature of this compound, which they have denominated by the exact appellation of *oxygenated muriatic acid*. In the action of the muriatic acid upon the black oxide of manganese, we observe the passage of this oxide to the red, the grey, and the white. In the last-mentioned state, it unites with the acid and forms a colourless salt; if we add a combustible body, the solution of the black oxide in this acid is effected without the formation of oxygenated muriatic acid. The properties of the muriate of manganese have not yet been described with accuracy. Bergman says that it affords crystals with difficulty, but only forms a deliquescent saline mass. However, it frequently happens in the laboratories, that large crystals of this salt are obtained, the form of which has not indeed been yet determined. The muriatic acid decomposes the sulphate of manganese.

38. The oxygenated muriatic acid oxidates manganese to the white state, quickly and without effervescence; it burns and inflames this metal when it is thrown in the form of powder or filings, into oxygenated muriatic acid. It also unites with the oxides of manganese, and forms solutions of the brown, red, or violet

colours, which afford crystals of the same tints. There is, therefore, an oxygenated muriate of manganese, the properties of which have not yet been discovered, and which it would be very important to examine.

39. The phosphoric acid does not unite immediately with manganese; it dissolves its oxides with difficulty: we may unite it with it by pouring a solution of an alkaline phosphate into that of the nitrate or muriate of manganese: we obtain a precipitate of phosphate of this metal. The case is the same with the fluoric acid, which also forms a fluoate of manganese of little solubility. The same is done with the borates.

40. Liquid carbonic acid attacks manganese as well as its black oxide; both are dissolved in it, though in small quantity. This solution, exposed to the air, gradually precipitates the oxides which separate at the surface in a white pellicle, if no oxide of iron be present. Bergman observes, that when we use the metal in this combination, an odour analogous to that of burned fat is disengaged.

41. We are not acquainted with the action of the four metallic acids upon manganese and its oxides, nor their combinations with this metal. We know, however, that the arsenious acid possesses the property of taking a portion of oxygen from the black oxide of manganese, and of passing in this manner into the state of arsenic acid, and that it whitens it at the same time.

42. In general, none of the solutions of manganese in the acids is decomposed, or rendered turbid by the contact of the air. The acids retain this oxide too strongly for it to absorb the atmospherical oxygen. The pure alkalis, and the alkaline earths, separate the oxide of manganese from them in a brown state, which quickly becomes darker coloured in the air, and by the mere contact of water containing air.

*I. Treatment by the Salifiable Bases, and the Salts.*

43. No action is exerted upon manganese by the earths; its oxide combines and vitrifies with them, imparting different colours to them, according as this oxide contains more or less oxygen, and is more or less charged with iron. In general, these vitreous crusts, or frits, are of the green, dark brown, blackish, or yellowish green colours; they are seldom red, unless we add to them some flux properly so called.

44. The pure alkalis promote the oxidation of manganese, and the decomposition of water by this metal, as they easily unite with the oxide. Scheele has well described the union of the fixed alkalis with the oxide of manganese. In the dry way, these two substances are fused together into a dark green mass, soluble in water, which it tinges green: when this solution is kept in a well-closed vessel, a yellow oxide of

iron

of the acid of nitre in the artificial manufactories of nitre.

46. Manganese and its oxides have no known action upon the sulphates: these salts, however, possess the power of depriving glasses coloured by manganese of their colour, when aided by a strong heat. The nitrates easily burn this metal, and strongly oxidate it; it is on this account that fused nitre gives a violet or red colour to glasses whitened by this oxide, by restoring to it the oxygen which had been taken away from it in the fusion of these glasses. The black oxides of manganese decompose the nitrate of pot-ash in the heat, by disengaging the acid, and combining with its base, with which they form a compound similar to that which is formed immediately with the alkalis.

47. The phosphates and the borates fused by the blow-pipe with the oxide of manganese, give colours which vary according to the state of this oxide, and according to the kind of fusion which they are made to undergo. Bergman and Scheele have given very accurate details concerning the phenomena of these combinations. A globule of phosphate of ammonia fused by the blow-pipe, with black oxide of manganese, gives it a blue-red colour, or a red colour, if we add more of this oxide. By heating it upon charcoal, or adding to it a little of this substance in the state of powder, its colour is dissipated with effervescence: this is not effected except with the interior blue flame of the

the blow-pipe; but if we employ only the white exterior flame, and the vitreous globule is thus exposed to the air, the colour re-appears with the same tinge. Nitre causes it immediately to re-appear, whilst sulphur, the sulphates, the metals, and many of the metallic oxides destroy it; the first of these substances yielding oxygen to the manganese, and the second depriving it of this principle. When we have discoloured a saline vitreous globule charged with manganese by its disoxidation, we may restore to it its former colours, by fusing it again for some time in a vessel of silver or platina, in contact with the air, which restores to it the oxygen of which it has been deprived. In the changes which take place so easily on a small scale in experiment with the blow-pipe, we observe a very sensible difference, if we produce them or attempt to produce them in crucibles. Carbon and sulphur act indeed as decolorant or disoxidant substances, and the nitre as a colorant or oxidant; but the sulphates and metallic oxides no longer produce the effects which they exhibit with the blow-pipe, since the contact of the air in one case, and of the combustible vapour of the blue flame in the other, act much more strongly upon the globules than analogous substances are able to act in a crucible.

48. Borax produces these phenomena with some slight differences in the colours; instead of the reddish-blue given to the phosphate, it is here of a yellowish-red; the saturation by the



oxide is indeed of a ruby-red in both cases. Carbon effaces here the colour more slowly and with more difficulty than in the phosphate, on account of the stronger adhesion which the oxide contracts with the borax.

49. These beautiful phenomena of coloration, given to the fluxes by the oxide of manganese in different states of oxidation, easily explain how this oxide clears glass. It is the oxide of iron which tends most commonly to colour the glass, and this oxide is not saturated with oxygen; when we add oxide of manganese, this last yields to the former all the oxygen which it wants in order to become colourless, and assumes the same cast itself by losing a portion of this principle. We see therefore why nitre restores the violet colour, by giving back the oxygen which it had lost. Many other metallic oxides, and in general all the combustible substances which are able to take this principle from the black oxide of manganese, and which frequently form a part of the vitreous combination which they colour, are equally discoloured by this oxide. Moreover, it is evident, that it must be added in a quantity proportionate to that of the colouring substances combined with the glass: if we add too little, the primitive colour remains; if we add too much, the oxide, which is not entirely dis-oxidated, colours with its own violet or reddish tinge, the glass that has an over-proportion of manganese.

K. *Uses,*

## K. Uses.

50. It is easily conceivable from all that has been said, that manganese and its oxide must be extremely useful instruments in chemistry; the first, as a metal which is extremely combustible, and absorbs oxygen from many other substances in order to pass into the state of white oxide; the second, in its black state or at the *maximum* of oxidation, by introducing into substances an abundant and very active portion of the oxygen which it contains. Accordingly, besides the oxygenated muriatic acid which this oxide forms, it may be employed in the analysis of many bodies; and notwithstanding the advanced state of the science, it may be confidently asserted, that the benefits which it has already derived from this beautiful metal, are nothing yet in comparison with those which it will derive from it hereafter,

51. The oxide of manganese is of great utility in the arts. Besides its use in the glass manufactories for purifying glass, on which account it has been termed the glass-maker's soap, it is employed in enamels, porcelain, &c. It is of importance here to remark, that the accurate knowledge which we now possess relative to the nature, the differences, and the distinctive properties of this oxide, according to its different states of oxidation, will, when  
it

it shall have become more generally diffused, and when it shall have been introduced into the manufactories of glass, porcelain, and enamels, afford a much surer guide to the artists in their operations, than the blind routine and fallacious empiricism by which they have hitherto been directed. In a word, both for the arts and for science, manganese is a substance, the study of which has already led, and will continue to lead, to the most useful and important results,

## ARTICLE XI.

### *Bismuth.*

#### *A. History.*

1. BISMUTH was known by the ancients, who gave it the name of tin-glass, which it has borne for a long time; amongst mineralogists, and especially since the appearance of the work of Agricola, when its differences, and those of its ores from other metals began to be the subject of inquiry, it has been successively named, according to the various and often erroneous notions which each author gave of it, *grey tin*, *grey lead* and *saturn*, *white antimony*, *white* and *silver-coloured marcasite*, *jovial*, *grey pyrites*, &c. &c. It is mentioned by the name of *magnesia* in Geber, by that of *demogorgon* in Glauber,

Glauber, of *nymph* in Van Helmont, of *glaure* in Augurellus.

2. Pott and Geoffroy the younger, in 1753, are the two first chemists who have studied its properties, and distinguished its specific characters with accuracy. Darcet and Rouelle have subjected it to a course of remarkable experiments. Monnet, and Baumè, have afterwards described its principal combination in a more detailed and exact manner than their predecessors. Bergman has given a still more accurate account of some of its combinations and its precipitates. The pneumatic doctrine has rendered its history much more exact and clear, though it has not yet been particularly occupied with the properties of this metal.

#### B. *Physical Properties.*

3. PURE bismuth is a brittle metal, of a white colour, verging towards yellow, presenting a texture of large brilliant and glittering plates. Its specific weight is 9,822; it appears to vary, according to its greater or less degree of purity, between the limits of 9,822 and 10,000. As it is hollowed a little by the strokes of the hammer before it breaks, and as it is not the most brittle of the metals of this order, Muschenbroeck found, that fused bismuth of 8,716, was brought by hammering to 9,638; notwithstanding this approach of its plates, they break under a violent stroke; they

they are reduced into a kind of small filaments, and even into a fine powder which may be passed through a silk sieve; in this state it is of a dirty grey colour.

4. With a little caution in dissecting it, we easily obtain a regular octahedron from a lamellated fragment of bismuth. Citizen Guyton, gives it the third rank with respect to hardness, and places it next to copper with regard to this property. Its elasticity is small; it has a peculiar smell and taste though they are slight and little perceptible; it easily conducts electricity and galvanism.

5. The dilatability of bismuth has not yet been estimated. It fuses very quickly and easily. Citizen Guyton ranks it with respect to this property between tin and lead, and determines its fusibility at the 205th degree of Reaumur's thermometer. It may be poured in the fused state into a cone of paper, without burning or even scorching it. If we suffer it to cool slowly after its fusion, it crystallizes in parallelopipedons which join or rather meet at a right angle, and are enveloped in one another, like the turns of a volute, such as are termed *à la Grecque*, because the Greeks have often employed this form in their architecture. In order to obtain this crystallization, we must wait till the bismuth is fixed at its surface, then perforate the crust, and pour off the fluid portion, not in order to leave a space sufficient for the regular arrangement of the molecules, as

Romè

Romè de Lisle imagined, for the crystals are formed in the midst of the liquid metal, like the salts in their solution,—but in order to lay bare the crystals that are already formed, and not suffer them to be inclosed in the whole of the fixed metal. Citizen Pouget has actually observed, that when the solid crust formed at the surface of the fused bismuth is taken away, whilst the lower part is still liquid, this crust exhibits well-formed crystals beneath. Of all the metals, this crystallizes in the most regular and easy manner: it is also the first metal which the chemists have caused to crystallize.

6. Bismuth heated for a long time, and violently after its fusion, sublimes and rises in vapour in well-closed vessels. It attaches itself and crystallizes in small brilliant filaments at the upper part of the apparatus, in which it is subjected to this high temperature. On account of this volatility, and at the same time of its brittleness, it was ranked amongst the semi-metals: it was said to be the heaviest of the semi-metals, and it was compared, with respect to them, to lead with respect to the perfect metals.

### *C. Natural History.*

7. THE ores of bismuth are not very numerous. There are only three that have been well distinguished from each other: the one is the native bismuth; the second is the sulphuret  
of

of bismuth, and the third is an oxide of this metal. That which has been termed arsenical ore of bismuth, is only an accidental mixture of bismuth with arsenic.

8. Native bismuth, which is very easily distinguishable by its colour, its brittleness, and its fusibility, which enables it to flow, when the gangues which contain it are placed at a small distance from the fire, or when the flame of a taper is applied to the fragments which then become every where covered with well-fused globules,—is still more distinguishable by its appearance and its form. It is found in small, yellowish, brilliant, triangular, or striated laminæ, in dendrites engaged in the gangue, or in regular octahedrons of the same colour, which are often very well pronounced: it may be cut by the knife, and it breaks easily under the stroke of the hammer. It is frequently found at Scala in Neritia, in Dalecarlia, at Schneeberg, at Bastnaës in Sweden. It is frequently mixed with arsenic interposed between its molecules.

9. The sulphuret of bismuth is an ore of a blackish-yellow colour, sometimes of a yellowish tinge, or in irregular masses much resembling those of the sulphuret of lead, or crystallized in pointed prisms, very like the sulphuret of antimony. Its fracture is brilliant and lamellated. The longitudinal divisions, as Citizen Haüy remarks, take place parallel to the sides of an hexahedral prism, and others are perceived.

ceived which are oblique to its bases. The smallness of the fragments has not yet permitted him to ascertain with accuracy the position of those different sections, and consequently to determine the primitive form of this mineral. The sulphuret of bismuth is distinguished from that of lead by its being fusible by the flame of a taper. When it is heated by the action of the blow-pipe, the white vapour which exhales from it attaches itself to the charcoal in an incrustation of a reddish-yellow colour, which becomes white by cooling. In this mineral the bismuth is combined with the sulphur in the metallic state; sometimes it appears that the bismuth contains iron. It was undoubtedly this circumstance that induced Cronstedt to admit an ore of bismuth and iron, mineralized by sulphur, in large cuneiform scales at Konigsberg in Norway.

10. The *native oxide of bismuth* : this which is frequently found with the native oxide of bismuth, or at the surface of the sulphuret of bismuth, is also sometimes insulated and deposited or disseminated upon stony gangues in granulated effervescences, of a greenish-yellow colour, very easily distinguishable by its cast. Mr. Kirwan believes that this oxide is combined with the carbonic acid. Bergman says that it is of a whitish colour, and very scarce.

D. Assay



*D. Assay and Metallurgy.*

11. THE assay of the ores of bismuth is one of the most easy and simple; it consists in mixing the ores, pounded and washed, with an eighth or a quarter of their weight of reducing flux, placing them in a lined crucible, well closed, and fusing them with a gentle heat and rapidly, in order to prevent the volatilization of the metal. Cramer especially recommends to perform this operation in well-closed vessels. A button is obtained which is to be accurately weighed.

12. Bergman directs as a means for assaying ores of bismuth, in the humid way, solution in the nitric acid: the solution is precipitated by means of water, as we shall see hereafter; and if the ore of bismuth contain any foreign metals, these remain dissolved after the precipitation of the former. The sulphuret of bismuth dissolves also in the nitric acid, by the aid of a slight ebullition; the sulphur separates from it in proportion as the oxidated metal passes into the acid; it is then washed; and its purity is ascertained by its burning without residue upon an ignited coal, and its quantity is determined by weight. The case is the same with the native oxide of bismuth; the nitric acid dissolves it; it is precipitated by water and iron, or cobalt: if the ore contains any, it remains in solution. Bergman asserts, that in precipitating the oxide of bismuth, dissolved

olved by the nitric acid, an hundred and thirteen parts of the oxide that is separated represent exactly one hundred parts of the metal taken away from the ore. The weight of the precipitate is equal to the dissolved portion when we assay a native oxide.

13. The working in the large way, or the metallurgy of the ores of bismuth, is not more difficult than the assay, on account of the easy reduction and fusion of this metal. Generally, in the places where the ores of bismuth abound, a pit of small depth is dug in the ground near the place where the ores are extracted; this pit is covered with billets of wood placed near each other, which are kindled, and the ore broken into fragments thrown upon them. The bismuth roasts, becomes oxidated, passes through the coals, is reduced, fused, runs, and collects in a cavity beneath, where it forms an orbicular cake. In this manner are formed those cakes of bismuth, convex on one side and flat on the other, and frequently crystallized at the flat surface, which we see hung up in the shops of our druggists.

14. In other places they incline over an hole dug in the earth, the trunk of a fir-tree, split in two and hollowed into a channel, upon which a bed of dry wood is laid and set on fire; the ore is thrown upon this fire; the metal runs along the channel in the trunk of the fir, into the hole or receptacle, where it collects, and whence it is taken out with iron ladles and

poured into moulds of iron, where it becomes fixed in ingots. We see by the short account of this work, which is the most simple of any in metallurgy, that bismuth cannot always be perfectly pure, and that it is not surprising that we frequently find sulphur in it, which is separated during its solution.

*E. Oxidability by the Air.*

Bismuth is but very slightly altered in the cold by the contact of the air; it only loses its brilliancy and becomes covered with a slight dust of a yellowish-grey colour; but it burns very easily, and quickly absorbs the atmospheric oxygen when it is heated, in contact with the air. Pott has observed, that by constantly agitating in the air, by means of the stalk of a tobacco-pipe, pulverized bismuth exposed to a very gentle fire, in a flat vessel, it was reduced into an oxide of a yellowish-grey colour, easy to be vitrified and reduced by combustible substances. As it becomes vitrified after its oxidation, it penetrates the pores of the cupels; and some authors have proposed to substitute it in the place of lead for cupellation, as being oxidized and absorbed quicker than the latter; but it has been observed that it flies about, and forms masses resembling mushrooms and cauliflowers, and that in this manner it might occasion a loss of the precious metals, as I shall show upon another occasion.

16. When we fuse bismuth in contact with  
the

the air, it quickly becomes covered with a pellicle exhibiting the prismatic colours, and by agitation, whilst the application of the heat is continued, it is changed into a powder or oxide of a greenish grey and sometimes of a brown colour, which has been termed ashes of bismuth. In this operation it increases by about a twelfth of its weight. If we continue to stir and heat it in the air, it assumes a yellow colour approaching to orange, and becomes a little heavier than it was before. Citizen Guyton reckons the augmentation of the weight of bismuth completely oxidated, at 0,25, which appears to me to be too much. Geoffroy the younger has observed, that when fused bismuth is heated to redness in an open crucible, it inflames with a slight explosion, emits a blueish light, and at the same time rises into the air in a yellowish smoke, condensable into what was then improperly termed *flowers of bismuth*, of the same colour. This oxide, which at last becomes very like *minium*, or the red oxide of lead, according to the same chemist, is not volatile, neither is it raised into vapour in the above-mentioned operation, except by the deflagration which the inflamed bismuth undergoes.

17. Citizen Darcet having exposed bismuth in bowls of the crude paste of porcelain, to the fire of the oven in which this earth is baked, constantly observed this metal to run out through a crack in the crucible, the external part of which it coated with a yellowish glass, whilst the oxidated and vitrified portion of the

the sulphur is never completely separated, except by the action of the nitric acid, greatly resembles the sulphuret of antimony, from which it may, however, be distinguished by an attentive examination, as it does not soil the fingers like the latter, as it is a little less fusible, and as the vapour which it yields before the blow-pipe, assumes a reddish tinge, whereas that of the sulphuret of antimony remains white, as has already been mentioned in treating of the ores of bismuth.

21. Sulphurated hydrogen gas colours the surface of bismuth, and strongly blackens the oxides of bismuth, which it brings towards the metallic state by reducing them to the state of sulphuret.

22. Bismuth is easily alloyed with many metals; but it does not unite without difficulty with most of those that we have already examined. In fact, its combination with tungsten, molybdena, chrome, titanium, and uranium are not known. That which it is capable of forming with arsenic, has also been hitherto ill described. Wallerius has remarked, that they cannot be united by fusion; it is known that in smelting it, it separates from cobalt, at the top of which it collects; that it, nevertheless, unites with this metal by the acid of nickel: its alloy with the latter affords, according to Cronstedt, a brittle, scaly, micaceous metal. It does not appear to be susceptible of uniting with manganese.

*G. Action*

*G. Action of Water and the Oxides.*

23. Bismuth exerts no action upon water; its attraction for oxygen is too weak to take it from the hydrogen. On the contrary, we find that this latter principle takes the oxygen from the oxides of bismuth, colours them, and causes them to return to the state of bismuth. It is true that hydrogen acts much more powerfully upon these oxides when it contains sulphur, since this seizes the metal at the same time that the hydrogen attracts the oxygen of the oxide of bismuth. From this double attraction proceeds the brown or green colour, which is imparted to the white oxide of bismuth, in so rapid and sensible a manner, by the vapours of the hydrosulphurets, or the hydrogenated sulphurets.

24. It is to be expected that a metal that has so little attraction for oxygen, or rather which has so slight an adhesion with this principle, will be able to take it from but very few metallic substances; accordingly bismuth does not act sensibly upon the metallic oxides, if we except those of the least combustible metals, with which it easily divides the oxygen which they contain; as it appears to yield a part of its own to other oxides. This fact is exemplified in the manufacture of porcelain, and in the preparation of enamels, where the colours are often seen to be modified by the mixture of these different oxides;

oxides; modifications which are owing merely to the distributions of oxygen amongst the different oxides which are mixed in the vitrifications.

#### H. *Action of the Acids.*

25. All the solutions of bismuth in the acids, and even the crystallized salts which are obtained from them, resemble each other, and differ from all or almost all the other metallic solutions, as well as from all their salts, in the circumstance that the addition of a sufficient quantity of water decomposes them, and precipitates from them an oxide of bismuth, of a more or less beautiful and brilliant white colour. This phenomenon shows that the bismuth is strongly oxidated by the action of the acids, that it has little adhesion with the solvents, and that it forms with them combinations of very little permanency; but it is very remarkable, that this metal should exist in them more highly oxidated than it is by the ordinary process of oxidation with the aid of fire and water, and that it should have a white colour, whilst the oxide, made in the ordinary manner, has only a dirty grey or yellowish cast. This phenomenon is found to take place in several and even in almost all the metallic substances.

26. The concentrated sulphuric acid exerts no action in the cold upon bismuth; but this metal decomposes the acid by ebullition; and  
by

by means of distillation, sulphureous acid gas is disengaged; the bismuth being oxidated and converted into a white powder. If we heat it strongly, sulphur is volatilized. When we wash this mass with water, the liquid takes up the remaining acid, and a small quantity of oxide of bismuth. The lixivium yields small, needled, and soft crystals by a well-managed evaporation: this sulphate of bismuth is decomposed by water, which separates from it a white oxide. The portion of this oxide, that is separated from the mass by the first lixiviation, does not sensibly retain sulphuric acid, and is reduced with much greater difficulty than the oxide formed by the action of fire and air.

27. The sulphureous acid does not attack bismuth; it unites with its oxide, and forms with it a white sulphite insoluble in water, and even in its acid, of a sulphureous taste, fusible by the blow-pipe into a reddish-yellow mass, which is reduced into metallic globules upon charcoal, decomposable with effervescence by the sulphuric acid, yielding by distillation sulphureous acid, and leaving also a white and pure oxide.

28. Nitric acid exerts a very lively action upon bismuth. When this acid is a little concentrated, and the bismuth in the state of powder, the re-action between the bodies is so violent, and the effervescence, the swelling, and the disengagement of nitrous gas, as well as the formation of the red and thick nitrous vapour which  
this



this gas produces in the air, are so rapid and active, that the whole of these phenomena present a striking example of a combustion which requires nothing except flame to render it complete: in fact, it is a real and very violent combustion, and is attended with a great production of heat. The bismuth is burned by the decomposition of the acid into white oxide, which, after the action has ceased, if the quantity of acid requisite for its oxidation have not been added, remains dry; sometimes in this operation the metal becomes inflamed and throws out sparks. If we take a weaker acid, no such violent action ensues; the oxide, in proportion as it is formed, is dissolved in the acid. It is observed, that a black insoluble powder is detached from the metal, which Pott considered as an oxide of bismuth, and which others have taken for sulphur: it is not yet known whether it is not charcoal. The nitric solution prepared in this manner is colourless, and deposits crystals frequently without evaporation. This salt has been described as having the form of tetrahedral prisms, compressed with obtuse trihedral summits: I have obtained it in flat rhomboidal parallelopipedons, resembling the Iceland crystal, but with much more obtuse angles. The nitrate of bismuth detonates feebly, and with small reddish scintillations upon ignited charcoal; it fuses, boils, swells, exhales nitrous vapour, and leaves a greenish-yellow oxide difficult to be reduced. It dries in a dry air, and in humid  
air

air it becomes a little moist and covered with a white and opaque pellicle. As soon as it is brought into contact with water, it renders it turbid, decomposes it, precipitates a white oxide, and affords only nitric acid with a very small quantity of water. This decomposition is effected with the nitric solution, which is poured gradually into a large quantity of water, in order to obtain the oxide, which was formerly termed *magistery of bismuth*, and which is still called pearl white in the shops, and is employed as a paint for the skin. If we wish to obtain this precipitate very white, and in a state of extreme division, in order that it may be very mild, it must be prepared with a large quantity of water, agitated for a long time, well washed, and dried with great precaution, and in places where there is no combustible vapour. Frequently it assumes a lamellated and brilliant form, like light mother of pearl, or the white scales of fishes. At least 113 parts are obtained from 100 of bismuth that have been employed; and as the water which dissolves the acid retains also a certain quantity of oxide which is separated by the addition of the alkalis, we must add a little more weight to the augmentation which this metal experiences in its oxidation by means of the acid; for Bergman reckons it only at 113 to the hundred, indicating only the oxide that is separated by the water. The oxide of bismuth obtained in this manner, when employed as a

white paint for the skin, has the inconvenience of being very easily turned to a dark grey, brown, or even black colour, by the contact of sulphurated or carbonated hydrogen gas, and even by that which is disengaged from hot, hard-boiled eggs, from privies, sewers, and from various boiled vegetables.

29. The muriatic acid acts with difficulty upon bismuth; in order to favour its action, it is requisite that it should be concentrated, and kept for a long time in digestion, or even distilled upon this metal reduced to powder. During this action a fetid smell is disengaged, which is probably owing to a particular hydrogen gas, though this has not yet been ascertained by experiment, since the metal being decomposed, as shall soon be shown, and the acid not being capable of being decomposed, there is only the water that can supply it with oxygen; and the other principle, the hydrogen, must be exhaled at the same time. By evaporating the acid that has been heated upon the bismuth, or by washing the mass which remains after the slow distillation carried to dryness, and by evaporating this solution, we obtain, though with difficulty, slender needles of muriate of bismuth in small quantity; for the greater part of the oxide of bismuth has been separated by the water. The muriate is sublimed by the action of the fire into a thick solid substance, fusible by a gentle heat, which was formerly termed *butter of bismuth*; it is deliquescent, decomposable by water, which separates from it a very fine white oxide.

30. The

30. The oxygenated muriatic acid oxidates bismuth with much promptitude and activity, and forms, with the oxide which it produces, the same salt as the preceding. If we throw pulverized bismuth into oxygenated muriatic acid gas, it becomes inflamed and throws out white sparks at the moment when it comes into contact with this gas. The vessel in which this experiment is made, is afterwards entirely covered with white oxide of bismuth. The action of the oxygenated muriatic acid upon bismuth is not known; it is not known whether these substances unite together, and whether there exist an oxygenated, muriate of bismuth, and in what respect it may differ from the simple muriate of this metal.

31. We are equally ignorant of the nature and properties of the combinations of the phosphoric, fluoric, and boracic, as also of the metallic acids, with the oxide of bismuth; the action of these acids upon the metal has not been appreciated. Its oxide, however, is combined with most of these acids, by pouring solutions of the alkaline salts which they form, into a solution of nitrate of bismuth. In this experiment we obtain white precipitates; we know also that there exists a carbonate of bismuth, for when we precipitate solutions of bismuth in the acids by means of the alkaline carbonates, we do not see the carbonic acid disengaged, at least not entirely; and the precipitate obtained by these

these salts weighs more than the oxide of the metal ought to weigh if it were pure.

32. All the solutions of bismuth by the acids are precipitated by the alkaline earths, the alkalis, and the alkaline carbonates, in a white powder. Bergman says, that a hundred parts of bismuth dissolved, yield by soda 125 parts of precipitate; by the carbonate of soda, 130; by the prussiate of pot-ash, 180. To all the facts that have already been indicated it must be added, that these solutions are never saturated, but always acid, though it seems that the oxide of bismuth itself is in a state approaching to acidity, especially with respect to its slight adhesion with its solvents.

#### *I. Action upon the Salifiable Bases and the Salts.*

33. The oxide of bismuth unites by the vitreous fusion with silica, to which it imparts a greenish-yellow tinge. The alkaline earths exert no sensible action upon this metal. Pott assures us that the fixed alkalis reduce bismuth in scoria; but there is reason to believe that this scorification depended upon the air and the vessels. Ammonia does not act upon bismuth; it is however asserted, that it assumes a yellowish colour with it. Margraff says, that its oxide dissolves well in this volatile alkali. The combination of the oxide of bismuth with the alkalis, deserves to be well examined by  
chemists,

chemists, as it promises combinations in which this oxide may act the part of an acid.

34. Bismuth produces no alteration, either in the sulphates or sulphites; it is burned and oxidated by the nitrates. When strongly heated and thrown into a red-hot crucible with nitrate of pot-ash, it detonates feebly without any rapid or brilliant inflammation; it is reduced into an oxide, of which one portion combines with the pot-ash. Pott asserts that bismuth is oxidated, dissolved, and sublimed by muriate of soda.

This metal does not act upon the muriate of ammonia, but its oxide decomposes it very well; even in the cold, it begins to disengage from it a small quantity of ammonia by simple trituration; and by heat it is totally decomposed, and leaves a muriate of bismuth which is sublimed entirely when acted upon by a strong fire. It here performs the functions of an alkali or a salifiable base.

The superoxigenated muriate of pot-ash burns bismuth with a flame, and oxidates it completely and very quickly, by the aid of heat, or the contact of an inflamed body. A mixture of one part of this metal in fine powder, and three parts of the salt, fulminates with the emission of sparks, when struck upon an anvil with a hammer.

The phosphates and phosphites, the borates, the fluates and the carbonates, do not act upon bismuth. These salts, which are frequently  
termed

termed the vitreous flux, on account of their property of vitrifying with many substances, are actually fused into a glass with bismuth, which gives them a yellow colour with more or less of a greenish cast, according to its different state of oxidation.

### K. *Uses.*

35. Bismuth, which has been compared with lead, but very improperly, since it differs from this metal in most of its properties, and since some points of strained analogy which Geoffroy the younger has found in it, are much fewer than the differing characters which it presents, is very frequently employed in its metallic form. It is alloyed with several metals, in order to give them hardness, rigidity, or consistence; it is particularly useful to the pewterers, and all those who employ white and hard alloys. It is generally believed that it acts upon the animal economy in the same manner as lead, though this opinion is yet supported by no decisive facts. In this state of uncertainty, and especially on account of the suspicion which all well-instructed authors have entertained of bismuth, it ought never to be employed internally except with much prudence and caution.

36. The utility of its oxides is very considerable. It is employed in this form by the manufacturers of porcelain in the preparation of some yellow enamels: it is mixed with other oxides,  
in

in order to tinge the colours of glazes and paintings. It is sometimes used in the manufacture of coloured glass, to give a yellow tinge approaching to green. The white paint or fucus is the most common preparation of this metal in the state of oxide. Besides the inconveniences which I have already mentioned, and which are not of sufficient consequence to prevent females from employing it, as the contact of the hydrogenated vapours may be avoided, a more important interest ought to dissuade them from its use. The oxide of bismuth injures the skin, either by obstructing its pores, or by constricting and irritating its texture, or by thickening, hardening and blackening it: it is employed for rendering the hair black. The Germans use the white oxide of bismuth, in doses of half a grain, as an antispasmodic and sedative in spasms of the stomach, especially with female patients. Mr. Reil has given us some observations on this property of the oxide of bismuth.

## ARTICLE XII.

### *Concerning Antimony.*

#### *A. History.*

1. THOUGH there are some reasons to believe that antimony was not entirely unknown to the ancients, but that they gave it another name



and employed it in some alloys; it is certain that its distinction as a particular metal, and the more profound investigation of its properties, are to be attributed to Basil Valentin, who flourished towards the end of the fifteenth century. It was in a first work professedly written upon the subject, and entitled *Currus Triumphalis Antimonii*, that he recorded many discoveries relative to this metallic substance, and especially its sulphuret; for it is to be observed that the name of antimony was given to the sulphureous combination of this metal, which was well known before it was understood how to extract from it the metal itself. Kerkringius, in the seventeenth century, commented upon the treatise of Basil Valentin; and his numerous notes contain, if not details, at least the first bases of all the discoveries that have since been made upon this substance.

2. No substance has been more studied than this, none has been the subject of such numerous labours, and there is none concerning which so much has been written. We might collect a library merely of the treatises that have been written upon this subject. The alchemists, who considered it as the substance the best adapted to the scope of their researches, have bestowed immense labours upon this mineral, and, if I may use the expression, have tormented it in every possible manner; in another point of view, it offered great motives for hope to the adepts, and many of them expected to find in it

3

the

the universal remedy. It would be difficult to enumerate the immense number of medicinal preparations that have been made with the ore and the metal that are to form the subject of this article. All persons who occupied themselves with chemistry, and the healing art, entertained for a long time exaggerated opinions relative to this subject. The one party could find nothing but excellent and powerful remedies in the antimonial preparations; the other considered them only as poisons, and thought they ought to be banished from medical practice. It was difficult to remain indifferent with respect to so important a substance, and hence arose the great number of experiments that were made, and the multitude of dissertations that were written upon antimony.

3. Lemery was the first chemist who, profiting by all the labours of his predecessors, and adding to them many of his own, began to write in a correct and rational manner concerning antimony. His Treatise, published at the end of the seventeenth century, contains a multitude of curious experiments and exact processes upon antimony and its sulphuret. Mender has also, in an express treatise, given a very complete history of it. Manget, in his *Bibliothèque Chimique*, has collected many treatises concerning the sulphuret of this metal. There exist many other particular and monographic treatises upon this body, and there has scarcely been any able chemist who

has not made some particular inquiries, some discoveries, or at least some essays relative to this substance. Geoffroy has inserted several memoirs relating to it in the volumes of the academy. Bergman published, in 1782, a very well written Dissertation concerning the numerous and varied sulphureous combinations of antimony. Scheele, Macquer, and Rouelle have also given different processes for preparing valuable antimonial remedies. A great number of physicians have invented and extolled particular formulas of which this metal and its sulphuret formed the base; of these we may form an idea from the Table of these remedies, published at London, in the year 1773, by William Saunders.

4. To these immense sources are to be added the innumerable antimonial preparations, that have been described and celebrated, for even more than eighty years past, in the pharmacopœias, formularies, dispensatories, all of which present some particular facts relative to its chemical history, and have had some influence upon the knowledge of the properties of this metal. Though it would be impossible as well as fastidious and useless to give an exact statement of all the discoveries contained in these almost innumerable works, we ought at least be sure of over-looking no essential circumstance in methodically arranging the exposition of the chemical characters of antimony; besides, we shall see that the  
thousands

thousands of experiments and inquiries that have been undertaken relative to this subject, refer to a certain number of general and leading facts, none of which shall be neglected or forgotten in this article. The pneumatic doctrine, by explaining with great clearness and extreme precision, all the discoveries and all the preparations that appertain to this metal, has greatly contributed to simplify its history; and the methodical nomenclature, by giving exact ideas of all the different compounds to which it gives rise, has dissipated the obscurity in which barbarous, mysterious, and ridiculous names had involved this part of chemistry.

#### B. *Physical Properties.*

5. ANTIMONY extracted from its ore and in a considerably pure state, or dug out of the earth which frequently affords it in a native state, as we shall soon see, has very distinct and well characterized properties. It is of a white, pure, brilliant colour, much resembling that of silver or tin; its lamellated texture is manifestly composed of plates which seem to intersect each other in every direction, and which have greatly embarrassed Citizen Haüy in dissecting them in order to determine its form. It frequently presents at the surface of those orbicular cakes, rounded and convex on one side, and flat on the other, which we meet with in the shops, very perceptible traces of crystal-

crystallization, which have been described as herborizations, fern-leaves, feathers, or starry rays. The alchemists placed a greater value upon that on which they saw this star shine, which they considered as a favourable omen for their labours. Its specific gravity is 6,702. Citizen Guyton places it in the seventh rank with respect to hardness, and at the side of lead; but it is sensibly harder than the latter, which it easily scratches: it has no ductility, and easily breaks under the stroke of a hammer. It may even be reduced into a fine powder, which is of a grey-white colour.

6. Its power of conducting heat, and its dilatability by this agent have not yet been determined with relation to other metals, for as it is not ductile, it is not necessary for the arts that this property should be ascertained. It is not fused until it has been heated to perfect redness, and it is ranked by the chemists amongst the metals of a middling fusibility. Citizen Guyton estimates a temperature of 345, according to Reaumur's scale, to be sufficient for fusing it. When we continue to heat it after its fusion in well-closed vessels, at the moment when it is of a white-red colour, it rises in vapour, and is sublimed and condensed at the upper part of the crucible in brilliant and manifestly crystallized laminæ. If we suffer it to cool slowly after having fused it, and if, by perforating the solid crust which forms at its surface, we suffer the liquid portion

tion to run out, we find the internal cavity left by this decantation lined with pyramidal crystals, small octahedrons, and several other secondary forms manifestly formed by octahedrons; when it becomes entirely fixed without any fluid portion being separated, it presents in its fractures large laminæ, which cross each other in various directions, and which, as I have already observed, render it very difficult to determine its form: this structure is the most complicated of any that Citizen Haüy has yet had occasion to observe. In masses of antimony purified by several repeated fusions, he has found, by attacking very sensible joints, twenty different directions; however, he has discovered this metal to be divisible in directions parallel to the faces of a regular octahedron, and at the same time to those of a rhomboidal dodecahedron; and he has found, by adopting the most probable hypothesis of this species of undetermined problem, that the octahedron, composed of an infinite number of small regular octahedrons connected by their edges, each of which was an assemblage of six smaller tetrahedrons united by their faces, by giving the primitive form, explains the almost infinite number of joints, the one parallel to the faces of the regular tetrahedrons, and the others to the faces of the tetrahedrons of which these are composed, which are found in the dissection of this metal: so that by this dissection,

fection, we arrive at the double result that has been announced.

7. Antimony has a very perceptible smell and taste, which are perceived when pieces of this substance have been held and rubbed for some time in the hands. It is to these properties that physicians ascribe the very decided effects which this metal produces in the animal economy, as an emetic and purgative. Some have, however, believed that it produced these effects only as an oxide, and when it met with acids in the first passages.

### C. *Natural History.*

8. ANTIMONY has hitherto been found in nature only in four different states: the first is that of native metal; the second, that of sulphuret of antimony; the third, hidro-sulphurated oxide of antimony; and the fourth, muriate of antimony.

9. *Native antimony* was first found, in 1748, at Sahlberg, in Sweden, by Anthony Shwab; Schreiber discovered it afterwards in abundance in the mines of Altemont, in the province formerly called Dauphiné, now the *Département de l'Isère*. This native antimony is easily distinguishable by its colour, its brilliancy, its large laminæ; sometimes it is mixed with arsenic; but this ought not to be considered as a particular ore as some mineralogists have done,  
who

who have designated it by the name of white or arsenical ore of antimony.

10. The sulphuret of antimony is of a grey metallic colour; it soils the fingers like black chalk, but its surface is much more brilliant, and never grows dull by friction. When this ore, which is very abundant in France and Hungary, is well crystallized, it presents square prisms, slightly rhomboidal, terminated by a pyramid with four faces, resembling that of the regular octahedron. This crystal divides very neatly parallel to the two most projecting or most acute edges of the prism; in the pyramid the divisions are parallel to the edges which answer to the bases of the prism; finally, by the light of a taper, we see some that are parallel both to the sides of the prism, and to its bases. Citizen Haüy has not yet found crystals sufficiently complete to ascertain the difference of some degrees necessary for determining the primitive form of this sulphuret. He only announces that the structure described seems to indicate a difference between the form that has hitherto been found, and that of the rectangular prism, or of the cube, or of the rectangular octahedron, which are the forms most familiar to the metallic substances. Mineralogists have greatly multiplied the varieties of the sulphuret of antimony, according to the arrangement, the separation, the union, the volume, and even the irregularity of the prisms or needles of this ore: such are the  
the



the *specular* sulphuret of antimony, the *striated*, the *needled*, the *stellated*, the *lamellated*, the *chatoyant*, the *coloured*, the *irregular*. They have also given it some names of other ores, when it is found to contain certain metals : and in fact, we frequently find in it silver and iron, as in that of Himmelfurst, near Freyberg : other samples are more or less charged with arsenic.

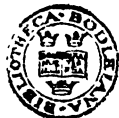
Amongst these varieties we must distinguish that which presents bundles of very thin needles, forming the transition to a capillary efflorescence, composed of grey silky and elastic fibres ; this is the ore of antimony in a grey-down, which Baron Born justly refers to the sulphuret of antimony.

12. *The hidro-sulphurated oxide of antimony*, termed *ore of antimony in red filaments*, or native *kermes* and *golden sulphur*, is found in fine shining filaments, of a deep and dark-red colour, disposed in radii diverging from a common centre, or in a kind of red incrustation, tarnished, adhering to the surface and in the cavities of the sulphuret of antimony ; it varies by its cast, which is sometimes light, but most frequently brownish, and by its crystalline or massy form, or crumbly state. It is now known to be a natural combination of oxide of antimony, sulphur and sulphurated hydrogen : it yields this last substance in the form of gas, with effervescence and a fetid odour, when it is treated by the acids ; it will  
be

be better known hereafter, when I shall explain its artificial preparation and its properties.

13. *The muriate of antimony.* This was for some time considered as a white oxide of antimony; it is found at the surface of other ores of antimony or upon different gangues, in two different forms; either in rectangular laminæ, of a brilliant and pearly white, divisible in a direction parallel to the larger laminæ, and resembling the stone termed *Stilbite*; or in small divergent needles, analogous in appearance to the radiated *Zeolite*, or to certain tremolites. It is immediately recognized by its property of fusing when exposed to the flame of a taper, and of emitting a vapour, which condenses and attaches itself in a white powder to the spoon in which it is held. This ore is very little abundant, and it is rarely met with.

#### D. *Affays and Metallurgy.*



14. **THOUGH** it is generally a matter of no interest to the arts to know the quantity of metal contained in the sulphuret of antimony, this knowledge is, however, frequently necessary in chemistry, and in the operations belonging to several of the arts. There are two processes by which the sulphur is separated, and the metal obtained in a pure state: the one consists in slowly roasting the ore till the greater part of the sulphur has been disengaged and burning the metal in a gentle fire, till it is reduced

reduced into a grey oxide, still sulphurated, which shall be described hereafter; and afterwards mixing this oxide with its weight of black flux and a small quantity of black soap or oil, and heating it pretty strongly in a crucible till the metal is well fused and collected at the bottom of this vessel. The black flux serves to reduce the oxide by its carbon, and to take away the remainder of the sulphur by its alkali. In the second process, which is more expeditious and frequently more certain, nitre is employed, the quantity of which is proportioned to that of the sulphur, in order that only the sulphur may be burned and the metal left alone. For this purpose, eight parts of sulphuret of antimony in powder, six parts of tartar, and three of nitre are taken. These three substances, accurately mixed and pulverized, are thrown by spoonfuls into a large crucible surrounded with charcoal, and ignited in a furnace which gives a strong heat. A lively detonation takes place at each projection; the tartar forms black flux, by its semi-combustion with the acid of nitre; and the sulphur of the sulphuret of antimony being burned, the metal is fused without being able to become oxidated on account of the carbon of the tartar with which it is surrounded, and the liquid alkali with which it is covered; the part of the sulphur which escapes the combustion, combines with the alkali and forms scoria, which swim at the top of the metal.

The

The whole is poured into a greased and well heated iron cone, then agitated, by striking the sides of the cone, in order to collect the antimony at the bottom of this vessel, and when it is sufficiently cooled, it is extracted in a button generally marked at its surface with needles disposed in the form of a star. This star proceeds from the circumstance that as the cooling commences at the sides, the fluid is thrown from the centre to the circumference. However, this crystallization can take place only in the small buttons of antimony: in the larger masses, such as the cakes which are sold in commerce, the fluid substance, being cast into flat moulds, experiences an undulation in several parts at the same time, and assumes several centres of crystallization; so that instead of a star, we find impressions resembling fern-leaves. Moreover, Reaumur has shown that a sudden refrigeration prevents the star-like crystallization, and that only the half of this star is obtained when one of the sides of the cone is suddenly cooled. Though the sulphuret of antimony contains nearly three quarters of its weight of metal, it is not obtained entire, because part remains in oxide combined with the sulphur and alkali in the scoria. Accordingly, these are very much compounded, as we find in them, by an exact analysis, undecomposed nitre, charcoal, sulphate of pot-ash, hydrogenated sulphuret of pot-ash, with sulphurated and hydrogenated oxide of antimony.

15. Bergman, in his Dissertation on the humid analysis, gives different processes for assaying the different species of ores of antimony. The native metal ought, according to him, to be treated with the nitric, or rather the concentrated nitrous acid, and reduced into oxide, the weight of which serves to determine its quantity and purity. The sulphuret assayed by the nitro-muriatic acid gives the sulphur separated upon the filtre. The metal oxidated and dissolved in the mixed acid being treated again with concentrated nitrous acid which is made to boil, is deposited in the state of oxide. The ores of antimony which contain arsenic, yield the latter separated, and show its proportion, when we cause them to boil slightly in the nitro-muriatic acid, in order to separate the sulphur from them; when we treat the solution which contains the antimony and arsenic with concentrated nitric acid which is brought to ebullition, the oxide of antimony then becomes precipitated alone, and is collected upon the filtre; by evaporating the liquor we obtain the arsenic in the state of arsenic acid; lastly, the same chemist recommends us to employ the caustic fixed alkali, which, he says, dissolves the sulphur and the antimony, and separates the silver or the other metals, which are not soluble in it. The last mentioned process is adapted to the cases of ores of antimony mixed with other metallic substances.

16. The

16. Operations in the large way, or the metallurgy of the ores of antimony, are applied only to the sulphuret of this metal: not to obtain the metal from it; for this extraction is performed only in particular works far from the mines; and in general the sulphuret of antimony is employed more abundantly and more frequently than its metal. Accordingly the working in the large way consists only in the purification and a sort of refining of this ore, for the purposes of separating it accurately from its gangue and affording it pure to the arts in which it is employed. With this view, a large crucible, or earthen pot, is placed in the ground, in such a manner that its sides are upon a level with the surface, or a little elevated above it: this is a sort of receiver; upon the first pot a second is placed, perforated at the bottom, which enters into the upper part of the first and closes it pretty exactly: this upper crucible is, therefore, entirely out of the ground; into this latter the ore which is to be purified is introduced, broken into fragments; it is covered with a lid; then surrounded with coals, and the fire lighted, which is at first made very gentle, and gradually augmented; the sulphuret of antimony runs through the holes with which the upper crucible is perforated, is collected in the crucible that is buried in the ground, and there becomes fixed by cooling. Some other fusible substances also pass, and form scoria above the fused ore. This  
sulphuret

fulphuret is afterwards extracted in cakes that have assumed the figure of the pot, and the mass of which, being throughout crystalline, is needled or striated in the interior parts. This is the state in which it is met with in commerce.

As the mineral, purified in this manner, is used in making a great number of chemical and pharmaceutical preparations; as it has been employed in these preparations much more frequently even than the metal, I shall, in each of the following articles, treat with each of the agents of which the action will be there examined, both of Antimony as well as the fulphuret of antimony, in order to present a more complete and more methodical history of the properties of this metal and of its ore.

*E. Oxidability by the Air.*

17. ANTIMONY is one of the most combustible metals, and unites most speedily and most strongly with the atmospheric oxygen. In the cold, it experiences no sensible alteration from exposure to the air; but when it is kept fused in contact with it, a white smoke arises which soon falls down upon the surface of the metal, or attaches itself to the upper part of the crucible, crystallizing there in the form of long and very slender prisms or of white shining needles. This sublimed and crystallized oxide was formerly termed  
*argentine*

*argentine flowers*, or *snow of regulus of antimony*. When we wish to prepare a certain quantity of it, we place a crucible filled with antimony obliquely in a good furnace, in such a manner that the mouth of the crucible is upon a level with the interior orifice of the hearth; upon the first a second crucible is adapted, supported obliquely and a little higher than the former, so as to serve as a receiver in this kind of subliming apparatus. These two vessels which are luted together with a little loam are not sufficiently closed to prevent the air from penetrating into the interior space. The metal becomes oxidized, burns with considerable violence and is at the same time volatilized, so that its oxide being received into the exterior crucible, is condensed in it, and attaches itself to it in long and beautiful crystalline needles, of a brilliant whiteness, and possessing a semi-transparency, of a vitreous appearance. A part of this oxide is pulverulent; it is detached by slightly shaking out the crucible which contains it upon paper. The antimony is found to have gained more than twenty per cent.

18. If, instead of treating the antimony in the manner that has just been described, it be heated very strongly and to whiteness in a crucible, and afterwards agitated or shaken in contact with the air, it inflames with a sort of explosion, presents while burning, a white light, and exhales into the air the white

Vol. V X oxide



oxide which it usually yields. This property is also observed in treating antimony in the small way with the blow-pipe. If when it is well fused upon charcoal, and at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules into which it divides in its fall burn with a very lively flame, and throw out on all sides brilliant sparks which last for some time: when we afterwards examine these globules which have been inflamed by rapidly absorbing and strongly solidifying the atmospherical oxygen, we find them covered with a white powder, or having deposited a light circle of this oxide upon the place where they rest, or where they have cooled. This pretty experiment we have from Citizen Gillet, member of the council of mines.

19. The white oxide obtained by the slow or rapid combustion of antimony, either crystallized or pulverulent, approaches to the nature of an acid substance. It is sapid, a little soluble in water; it is easily reduced by carbon; it remains fixed in the fire; and it fuses at a high temperature into a glass of a clear hyacinth colour. It is employed for colouring glasses with an orange, or saffron-yellow tinge.

Citizen Thenars, in his interesting researches relative to the oxides of antimony, has found that this retains 0,20 of oxygen, that it is easily reduced, even without any addition, and that by operating in a tube of porcelain

we

we may obtain the metal by the mere action of the fire; that if we heat it strongly and cautiously in a crucible, it passes, as it becomes successively difoxided, first into the state of a yellow oxide easily fusible into glass, containing 0,19 of oxygen, then into the orange-coloured oxide, containing 0,18 of this principle; afterwards into chocolate brown oxide, charged with 0,16 of oxygen; and lastly, that it arrives at the state of black oxide, containing only 0,02 of oxygen, before it re-assumes the metallic state. These different oxides are of great importance to be known, on account of their relation with several antimonial combinations that will be described hereafter.

20. The sulphuret of antimony, heated upon charcoal, with the blow-pipe, is fused, runs, exhales a white smoke which attaches itself to the coal in a powder of the same colour, and at last penetrates the substance which supports it, and disappears leaving a white circle round the place where it has been absorbed. When this sulphuret is exposed in the state of a fine powder to a slow fire, upon an earthen plate, so as to have much contact with the air, and frequently agitated, it is converted after the application of the fire has been continued about fifteen or eighteen hours, into a greyish powder, frequently mixed with particles that are still brilliant, and which easily forms soft lumps when it is heated a little more strongly. This

powder which was formerly termed *grey calx of antimony*, and at present *grey fulphurated oxide of antimony*, is oxidated antimony that has lost the greater part of its sulphur. The sulphuret when converted into this species of oxide, is diminished in the proportion of between twenty two, to twenty three parts in a hundred. Bergman admits that it contains, in a hundred parts, about five parts of sulphur, so that the grey fulphurated oxide of antimony seems to consist of about 0,78 of antimony, 0,16 of oxygen, and 0,06 of sulphur. This oxidation, and desulphuration of the sulphuret of antimony affords a sulphureous smell, and raises into the air a small quantity of oxidated antimony; when the operation is performed upon a large quantity of the substance, this vapour is pernicious, at least unless it be performed under a chimney that has a good draught. The ancient chemists supposed the existence of some arsenical matter in the sulphuret of antimony; but it produces this effect by the peculiar nature of its oxide.

21. When we heat the grey fulphurated oxide of antimony rapidly, and with the aid of a strong bellows, it is fused in the space of some minutes into a beautiful transparent glass of a hyacinth colour. This is the glass of antimony of the ancient chemists, the transparent vitreous fulphurated oxide of the systematic nomenclature. It is to be remarked that when the oxidation and the roasting of the sulphuret has

been continued till all its brilliancy has disappeared, and till it is whitened or approaches to whiteness, we have only an opaque scoria; which shows that the presence of some hundredths of sulphur is requisite to the preparation of this glass. Accordingly, in order to give it its transparency and beauty, it is sufficient to add to it a little sulphur or sulphuret of antimony, which even greatly accelerates the fusion. When, on the contrary, we heat the grey sulphurated oxide of antimony with twice its weight of black flux, or still better with a mixture of one part of white flux, and one part of tartar, in a crucible, with a good fire, for some minutes, we obtain 0,78 or 0,79 of pure antimony. I have already indicated this process in the description of the assays of this ore.

22. In order to prove the nature of the glass of antimony by synthesis, Bergman combined oxide of antimony immediately with sulphur, in the proportion of eight parts of the first, and one of the second; by fusing this mixture in a crucible, with the blast of the bellows, he obtained real vitreous and transparent sulphurated oxide of antimony. He has remarked that by fusing for the same space of time, about seven minutes, two parts of oxide, and one part of sulphur, the sulphur was volatilized, and that the sulphur being thus fused, and sublimed with a strong fire, carried with it the oxide of antimony; that four parts of oxide with

with one of sulphur gave a black, and as it were fibrous mass, whilst sixteen parts of oxide, and one of sulphur yielded a greenish glass. He adds, as a character of the glass of antimony, that when heated with the muriatic acid, it exhales sulphurated hydrogen gas. He proposes with reason to prepare the glass of antimony for pharmaceutical purposes, by combining the oxide of antimony with the sulphur in the first proportion that has here been indicated, in order to have this preparation constant. He has taken for his experiments the oxide of antimony formed by means of nitre; but it is to be remarked that, that which is the product of oxidation in the air is affected very nearly in the same manner as the former.

*E. Union with the Combustible Substances.*

23. It is not known whether there exists any combination between antimony and azote, hydrogen and carbon, which, amongst the combustible bodies, have yet shown but very little action upon most of the metallic substances. Carbon acts with much energy upon the oxide of antimony, deprives it of its oxygen at a red heat and reduces it. The hydrogenated compounds, or the carbonated hydrogenous substances, the oils, the resins, the fats, produce the same effect upon this oxide at a very high temperature, and cause it to return into the metal-

metallic state. This operation has however always been considered as difficult. It has been said that it succeeds only in part, and that but very little well-reduced antimony is obtained. In fact, the mass, after having been strongly heated, frequently remains in the state of a black, spongy, inflated scoria, and this scoria is commonly pyrophoric; it inflames and burns with rapidity, like a fire-work, when the matter contained in this vessel is stirred with an iron rod. However the experiments of Citizen Thenars have rendered these phenomena easy to be accounted for; it appears that the carbon opposes the fusion of the antimony, that its white oxide returns into the state of black oxide, and remains in this state in a light and scorified form, in which it is generally pyrophoric.

24. Antimony unites very well with phosphorus. Pelletier, who is the first who has occupied himself with the preparation and the properties of the metallic phosphorets has formed that of antimony in three ways, either by heating one part of vitreous phosphoric acid with one part of antimony, and an eighth of carbon, or by fusing equal parts of this vitrified acid and antimony in powder without carbon, or by throwing phosphorus upon the metal in the fused state, in a crucible. The second of these processes proves that antimony heated to redness has more attraction for oxygen than phosphorus has, as the phosphuret of  
antimony

antimony which is formed in this case cannot be formed without the acid glass being decomposed and unburned by the metal. By every one of these three means, Pelletier has obtained a brilliant metallic phosphuret, brittle, of a lamellated fracture with small square facets, similar and equal in three processes. This phosphuret, when placed upon a well-ignited coal, is fused, yields a small green flame, and exhales white oxide of antimony. Pelletier observes, that this phosphorated combination resembles that of arsenic with the same metal, in the form of its small facets. It appears that it is more fusible than antimony. This combination, like all those of the metals with phosphorus, has yet been only touched upon, or but very slightly examined, and it merits all the attention of chemists.

25. Antimony combines easily with sulphur, and forms, by this artificial combination, a sulphuret of antimony perfectly similar to that which exists in nature. On fusing the mixture, we perceive that it is much more fusible than the metal itself; that this absorbs only a little more than a quarter of its weight of sulphur; that it assumes the prismatic or needled form, and the brilliant grey colour, instead of the lamellated texture and the white colour which it had before. We may bring this artificial sulphuret of antimony to crystallize like the natural one, by causing it to cool slowly, and by separating the portion which is still liquid;

liquid; in other respects it acts in all experiments like the native sulphuret of antimony, and might be employed and prepared for the same uses, if nature did not afford it in great abundance.

26. Antimony combines easily with many metallic substances. In general, its alloys are lamellated and brittle. Amongst the metals that have hitherto been examined, we only know the combination of antimony with arsenic and bismuth. We know that these alloys have small facets, that they are very brittle, very hard, and easy to be fused. Those which it forms with tungsten, molybdena, titanium, uranium, nickel, cobalt, and manganese, have not yet been examined. These metals have, for the greater part, been too little examined hitherto for it to be possible to determine with precision their combinations with each other, or with other metallic substances.

27. As little has the action been yet appreciated which various combustible bodies, especially hydrogen, carbon, and phosphorus, exert upon the sulphuret of antimony. Sulphur cannot act upon it, as the metal is already saturated with it in this combination. However we shall see hereafter that by adding sulphur in some combinations, the properties of the resulting compounds are singularly modified. Several metals, amongst those which remain to be examined, possess the property of taking away the sulphur from antimony in a red heat,



heat, and of decomposing its sulphuret, as will be shown in the history of these metals. The alchemists formerly made great use of this property, and placed great confidence in what they termed the *Regulus*, or the alloyed antimony, proceeding from this operation.

28. It has already been proved (No. 22.) according to the experiments of Bergman, that the oxide of antimony, heated and fused with sulphur, forms vitreous compounds more or less of a hyacinth colour, which resemble the glass of antimony. We shall here add, that in these combinations, sulphurated hydrogen gas is produced, which unites with the oxide and the sulphur, so that these compounds are hidro-sulphurets, or hidro-sulphurated sulphurets. This proceeds either from the circumstance that the oxide which Bergman advises us to take retains a little water; for he recommends it to be well washed, and we shall see hereafter for what reason; or that the combination absorbs atmospherical water, and decomposes it: the latter fact indicates that the oxide of antimony here acts after the manner of the alkalis. The Swedish chemist observes, that the glass of antimony, prepared in this manner by fusion, yields sulphurated hydrogen gas when it is heated with the muriatic acid, whilst a simple mixture not fused, but merely triturated, of the oxide of antimony and sulphur, does not yield gas by the action of this acid. The union between the  
two

two substances, effected by fusion, is therefore necessary to the decomposition of water.

29. We have also seen (No. 22.) that, according to the proportions of oxide of antimony and sulphur, which we combine by fusion, we obtain different compounds. I ought here to add, according to Bergman, (Experiment 36, in his Dissertation on the Sulphurated Antimonials) that by heating in a crucible equal parts of oxide of antimony, retaining a little water, according to his method of preparing it, and sulphur, with a gentle fire raised only to the degree necessary for fusing or slightly softening the mixed mass, a brown compound is obtained, analogous to the preparation known by the name of *Kermes Mineral*, of which I shall speak hereafter. Here, still more than in the Artificial Composition of the *Glass of Antimony*, which has been spoken of in Nos. 22 and 28, sulphurated hydrogen is formed, which enters into the combination; for the Kermes contains more of this substance than the glass of antimony. By the explanations that will be given, this simple enunciation will soon be comprehended.

30. A combination, very analogous to these hydro-sulphurets of antimony, is effected by a process which had escaped the sagacity of Bergman, and which Citizen Berthollet has lately applied to great advantage, though it has hitherto been seen and indicated but in a vague manner by most chemists. Whenever the oxide  
of

of antimony is treated with an alkaline sulphuret, or with an hidro-sulphuret, such as water charged with sulphurated hydrogen, this oxide unites with the latter, and at the same time with a greater or less quantity of sulphur, so as to form compounds more or less of an orange or brown colour, in which the antimonial oxide and the sulphurated hydrogen are the common elements, but which vary from each other in a very great number of proportions, followed by gradations very much diversified in all their properties. As these compounds will come to be treated of more in detail, under the article relating to the treatment of antimony, and its sulphurets by the alkalis and by nitre, I here indicate only the existence of these compounds, and their formation by the immediate union of sulphurated hydrogen, and the hydrogenated sulphurets, with the oxide of antimony.

*Action upon Water and the Oxides.*

31. THE reciprocal action of water and antimony has not yet been sufficiently examined: in the cold, these two substances produce no sensible effect upon each other; but the same is not the case when the antimony is heated to redness and fused. It cannot be doubted that in this case the metal decomposes the water; it has not been practicable to perform this experiment in an immediate manner, because it is accompanied with a very dangerous detonation and fulmination

fulmination. Chemists have frequent opportunities of observing this fulguration, which takes place whenever fused antimony is in contact with water: in two of these accidents, both of which might have killed or grievously wounded the operators, I remarked a very brilliant white flame. I have no doubt, therefore, that the water, at a high temperature, is decomposed by the antimony, and that the latter burns by the oxygen which it takes away from it; and we shall soon see that the same decomposition takes place in the cold or in a slight heat, under a multitude of circumstances, in which the antimony is assisted by the addition of several other bodies.

32. Though the action of the sulphuret of antimony upon water has not yet been studied, many facts concur to prove that it exerts a more or less marked action upon this liquid, and that it takes from it its oxygen, even at temperatures considerably low, provided it be assisted by the simultaneous action of the acids or the alkalis. It is this action, the knowledge of which was unfortunately wanting to Scheele and Bergman, which would have enabled them to discover still more important truths than those which we already owe to their genius, and which, as we shall see in the subsequent numbers, renders it much more easy and simple to comprehend and explain several phenomena which they observed and described, relative to the antimoniated preparations,

limed: there then remains white oxide of antimony in the vessel. If we do not urge the application of the heat to dryness, we have a white, soft, and humid mass in the crucible; when we wash this mass with water, the liquid takes up the acid united with a small portion of antimony, and leaves a large quantity of white oxide undissolved; a large quantity of water added to this solution precipitates from it also the small quantity of oxide which it contains: when it is evaporated, it becomes turbid without affording any real crystallized salt. The earths and alkalis decompose it, and precipitate from it a white oxide, which is difficult to be reduced by carbon, according to the testimony of most chemists. There exists, therefore, no real sulphate of antimony, and the metal, though very oxidable by the boiling sulphuric acid, is not soluble in this acid, so that it acts almost as if it had itself assumed the character of acid.

37. The sulphuret of antimony is scarcely attacked by the sulphuric acid; when this acid is boiling, it effervesces with the mineral; much sulphureous acid gas is disengaged, but no sulphurated hydrogen gas; there is no more oxide of antimony in solution than in the preceding case; the sulphur, mixed with the oxide of antimony, remains at the bottom of the liquid; accordingly, this cannot be a process proper for analyzing the sulphuret of antimony, and separating the sulphur from the metal. The oxide  
of

of antimony by fire, the grey sulphurated oxide, and the glass of antimony are scarcely attacked by the sulphuric acid. When we cause it to boil upon the coloured hidro-sulphurated oxides, that have been treated of in Nos. 22, 28, 29, and 30, a small quantity of sulphurated hydrogen gas is disengaged, without taking up the oxide and really separating it from the sulphur.

38. The sulphureous acid exerts no action in the cold either upon antimony or the sulphuret of antimony; in heat it appears that this acid is decomposed, that the metal is oxidated, and that a sulphurated sulphite of antimony is formed. The sulphureous acid takes the oxide of antimony from several of its solutions, and especially from that by the muriatic acid; it forms in it a white precipitate, of an acrid and austere taste, a true insoluble sulphite of antimony, volatile, and decomposable by the action of the fire, fusible previous to its decomposition into a grey mass, crystallizable at its surface, and hollow in the interior part, which is lined with small crystals; reducible by carbon, from which the sulphuric expels the sulphureous acid, and which, in close vessels, yields by distillation a small quantity of sulphureous acid, and afterwards sulphuric acid, leaving as residuum a substance of a brown colour, soluble in fixed alkali, and precipitable into a hidro-sulphurated oxide of antimony by the muriatic acid.

39. The nitric acid, and especially that which contains a small quantity of nitrous gas is rapidly decomposed by antimony, even in the cold. During this action a large quantity of nitrous gas is produced, accompanied with a very strong red vapour; the rapidity of the oxidation of the antimony, which is instantaneously converted into a white oxide, presents the idea of a real combustion. Sometimes also inflammation takes place. Not only the nitric acid is decomposed in this experiment, but the water itself is partially so: so powerful is the attraction which the antimony exerts in this case upon the oxygen; the union of the azote of the first, with the hydrogen of the second of these substances, produces ammonia, which combines with the nitric acid, and forms nitrate of ammonia, which has been taken for a portion of oxide united with the acid. When we treat the white and thick, or even dry mass, which results from this action, with quick-lime, or the caustic fixed alkalis, the ammonia is disengaged. There is no combination between the oxide of antimony and the undecomposed portion of the nitric acid, when any of this remains. If there be a little of this oxide dissolved in the acid, water precipitates it; we might say, that the antimony had passed into the acid state, on observing the slight adhesion which it contracts with the nitric acid. The oxide formed by this process has been considered as extremely difficult to be reduced; the metal cannot be extracted

extracted from it without a great deal of labour. It is justly considered as one of the most refractory and irreducible acids that exist. Citizen Thenars, on examining it comparatively with some other white oxides, has found it to contain 0,30 of oxygen; it approaches to that which is produced by nitre; he has found it to be in fact difficult of reduction, but he has easily succeeded in reducing it by heating it with a small quantity of antimony, in order to deprive it of its oxygen: by this means he has caused it to pass successively through the yellow, orange and brown colours, which indicate, (as I have already said relative to that which is made by the fire, and which contains 0,20 of oxygen,) progressive diminutions of its oxidation.

40. The sulphuret of antimony is also attacked with violence, to use the common mode of expression, by the nitric acid, especially when we promote its action by caloric; the metal is oxidated and none of it remains in the acid: the mixture becomes much heated; a large quantity of nitrous gas is disengaged, but no sulphurated hydrogen gas; the sulphur which is separated, is found confusedly mixed with the oxide of antimony at the bottom of the liquor; and we see accordingly from this fact that the nitric acid cannot be used in the concentrated state, particularly for making the assay of the sulphuret of antimony.



41. This acid exerts no action upon the oxide of antimony; it is not improbable that it may be dissolved by the nitrous acid, on account of the property which this possesses, of absorbing a certain portion of oxygen from many metallic oxides. It has not however been attempted; neither is the manner known in which the nitric and the nitrous acids act upon the sulphurated oxides of antimony, or upon the hidro-sulphurets of antimony. It is only known that the sulphurated hydrogen is not disengaged by the nitrous acid, but burned.

42. The muriatic acid appears to be that which of all acts with the greatest difficulty upon antimony. The chemists who have particularly occupied themselves with the solution of metals, have said that this metal dissolves by long digestion or by distillation in the muriatic acid. I have observed, that when this acid is left for a long time upon antimony in powder, it at length acts upon this metal, and dissolves a sufficient quantity of it to assume a somewhat yellowish colour from it. This solution can only take place when the metal is oxidated, and its oxidation in the case that has been quoted, can only proceed from the decomposition of the water; however I have remarked no effervescence, or it has been so feeble, and at such distant intervals, that I have not been able to perceive it. The white oxide of antimony dissolves better in this acid,  
and

and forms a colourless solution, which has some properties different from those of the preceding; the one yields by evaporation small crystals in deliquescent needles which are volatilized by the fire, and are precipitated and decomposed by the contact of water; that of the oxide, according to Citizen Monnet, is fixed in the fire, and crystallizes into brilliant laminae like the boracic acid; besides it is decomposable by water. This difference would deserve to be confirmed by new observations. Bergman affirms that the muriatic acid has more attraction for the oxide of antimony than the other acids: this is proved in fact by the solution of them which it effects; whilst the preceding acids oxide the antimony without dissolving it, or quit it very readily.

43. The muriatic acid dissolves the sulphuret of antimony better, as it can operate without the aid of heat. During the solution, a strong smell of sulphurated hydrogen gas is disengaged. When we heat the mixture the whole of the metal is dissolved. According to Bergman, a docimastic quintal of sulphuret of antimony, heated with the muriatic acid, yields about eleven cubic inches of sulphurated hydrogen gas; besides a small quantity which remains in the water through which the gas passes. The same quantity of sulphuret of antimony yields only two inches of this gas, when it is treated in the cold with the muriatic acid. This celebrated chemist remarks, that the gas carries

41. This acid exerts no action upon the oxide of antimony; it is not improbable that it may be dissolved by the nitrous acid, on account of the property which this possesses, of absorbing a certain portion of oxygen from many metallic oxides. It has not however been attempted; neither is the manner known in which the nitric and the nitrous acids act upon the sulphurated oxides of antimony, or upon the hidro-sulphurets of antimony. It is only known that the sulphurated hydrogen is not disengaged by the nitrous acid, but burned.

42. The muriatic acid appears to be that which of all acts with the greatest difficulty upon antimony. The chemists who have particularly occupied themselves with the solution of metals, have said that this metal dissolves by long digestion or by distillation in the muriatic acid. I have observed, that when this acid is left for a long time upon antimony in powder, it at length acts upon this metal, and dissolves a sufficient quantity of it to assume a somewhat yellowish colour from it. This solution can only take place when the metal is oxidated, and its oxidation in the case that has been quoted, can only proceed from the decomposition of the water; however I have remarked no effervescence, or it has been so feeble, and at such distant intervals, that I have not been able to perceive it. The white oxide of antimony dissolves better in this acid,  
and

and forms a colourless solution, which has some properties different from those of the preceding; the one yields by evaporation small crystals in deliquescent needles which are volatilized by the fire, and are precipitated and decomposed by the contact of water; that of the oxide, according to Citizen Monnet, is fixed in the fire, and crystallizes into brilliant laminae like the boracic acid; besides it is decomposable by water. This difference would deserve to be confirmed by new observations. Bergman affirms that the muriatic acid has more attraction for the oxide of antimony than the other acids: this is proved in fact by the solution of them which it effects; whilst the preceding acids oxide the antimony without dissolving it, or quit it very readily.

43. The muriatic acid dissolves the sulphuret of antimony better, as it can operate without the aid of heat. During the solution, a strong smell of sulphurated hydrogen gas is disengaged. When we heat the mixture the whole of the metal is dissolved. According to Bergman, a docimastic quintal of sulphuret of antimony, heated with the muriatic acid, yields about eleven cubic inches of sulphurated hydrogen gas; besides a small quantity which remains in the water through which the gas passes. The same quantity of sulphuret of antimony yields only two inches of this gas, when it is treated in the cold with the muriatic acid. This celebrated chemist remarks, that the gas carries

41. This acid exerts no action upon the oxide of antimony; it is not improbable that it may be dissolved by the nitrous acid, on account of the property which this possesses, of absorbing a certain portion of oxygen from many metallic oxides. It has not however been attempted; neither is the manner known in which the nitric and the nitrous acids act upon the sulphurated oxides of antimony, or upon the hidro-sulphurets of antimony. It is only known that the sulphurated hydrogen is not disengaged by the nitrous acid, but burned.

42. The muriatic acid appears to be that which of all acts with the greatest difficulty upon antimony. The chemists who have particularly occupied themselves with the solution of metals, have said that this metal dissolves by long digestion or by distillation in the muriatic acid. I have observed, that when this acid is left for a long time upon antimony in powder, it at length acts upon this metal, and dissolves a sufficient quantity of it to assume a somewhat yellowish colour from it. This solution can only take place when the metal is oxidated, and its oxidation in the case that has been quoted, can only proceed from the decomposition of the water; however I have remarked no effervescence, or it has been so feeble, and at such distant intervals, that I have not been able to perceive it. The white oxide of antimony dissolves better in this acid,  
and

and forms a colourless solution, which has some properties different from those of the preceding; the one yields by evaporation small crystals in deliquescent needles which are volatilized by the fire, and are precipitated and decomposed by the contact of water; that of the oxide, according to Citizen Monnet, is fixed in the fire, and crystallizes into brilliant laminæ like the boracic acid; besides it is decomposable by water. This difference would deserve to be confirmed by new observations. Bergman affirms that the muriatic acid has more attraction for the oxide of antimony than the other acids: this is proved in fact by the solution of them which it effects; whilst the preceding acids oxide the antimony without dissolving it, or quit it very readily.

43. The muriatic acid dissolves the sulphuret of antimony better, as it can operate without the aid of heat. During the solution, a strong smell of sulphurated hydrogen gas is disengaged. When we heat the mixture the whole of the metal is dissolved. According to Bergman, a docimastic quintal of sulphuret of antimony, heated with the muriatic acid, yields about eleven cubic inches of sulphurated hydrogen gas; besides a small quantity which remains in the water through which the gas passes. The same quantity of sulphuret of antimony yields only two inches of this gas, when it is treated in the cold with the muriatic acid. This celebrated chemist remarks, that the gas carries

carries with it, and deposits in the tube of glass which conducts it a small quantity of kermes, or red hidro-sulphurated oxide of antimony, which proves that the water is decomposed; for the kermes contains antimony in the state of brown oxide, and also sulphurated hydrogen. The vitreous hidro-sulphurated oxide of antimony, or the glass of antimony is equally dissolved in the muriatic acid, with a disengagement of sulphurated hydrogen gas. It is however here to be observed, that this latter compound, which is obtained by fusing oxide of antimony with an eighth of its weight of sulphur, may probably be nothing more than a simple sulphurated oxide, and not an hidro-sulphuret, as we find with the alkaline sulphurets; and as these suddenly form hydrogenated sulphurets by the contact of water, and the liquid muriatic acid, it may well be the case that the sulphurated oxide of antimony does not contain sulphurated hydrogen, and that this is formed only at the very moment of the contact of the muriatic acid, and by the decomposition of the water. This may probably be the nature of the difference between the *glass of antimony*, and the *kermes mineral*.

44. The oxygenated muriatic acid burns and inflames antimony with rapidity, when we throw this metal into the gaseous acid; in proportion as the metallic powder touches this gas, each portion kindles and burns with a very brilliant white flame, which forms sparks. The  
metal

metal falls in the state of oxide to the bottom of the vessel. In the liquid oxygenated acid the antimony is converted into a white powder, of which only a very small portion remains dissolved in the muriatic acid, on account of the large quantity of water which this liquid oxygenated acid contains, in which, as we recollect, it has very little solubility. The case is the same with the sulphuret of antimony, the sulphurated grey oxide, and the sulphurated vitreous oxide of antimony; these three antimonial sulphurets, when thrown into oxygenated muriatic acid gas, burn with a blue flame, because it is only their sulphur which is inflamed; and as it passes thereby into the state of sulphuric acid, I advise to treat these bodies with the liquid oxygenated muriatic acid in order to analyze them, and to ascertain the quantity of sulphur by that of the sulphuric acid that is formed, which is determined by the acid of the muriate of barites; and that of the metal, or of the oxide by the weight of the first precipitate or white deposition, which is separated in this experiment. This method will have, it is true, the slight inconvenience of yielding an oxide more charged with oxygen than it was in the sulphurated antimonials; but this is a very slight error; it requires only a subtraction of 0,02 or 0,04 of the oxygen of the precipitate obtained.

45. The nitro-muriatic acid has long been considered as the best solvent of antimony,  
and



and in fact it oxidates and dissolves it without reducing it into white pulverulent and insoluble oxide like most of the preceding. This nitro-muriatic solution is more permanent than the others. However it is also decomposable by water, and yields white oxide of antimony. There is no nitro-muriate of antimony, as some authors have pretended, but muriate of antimony in this solution. This liquid salt, the only permanent one, in which the oxide of antimony remains united with an acid, affords when we plunge iron or zinc into it, a blackish precipitate, a species of oxide of antimony containing 0,02 of oxygen, which, according to the observation of Citizen Thenars, becomes pyrophoric, and inflames spontaneously in the air, when dried with a gentle heat.

46. The sulphuret of antimony is very well, and accurately decomposed by a mixture of three parts of muriatic acid, and one part of nitric acid. The metal is completely dissolved and the sulphur remains alone, provided we employ a sufficient quantity of the solvent, and cause it to boil slightly towards the end. When the action of this is terminated, 0,26 of pure sulphur are obtained. During the solution a strong smell of sulphurated hydrogen gas is disengaged; and nevertheless, according to the observation of Bergman, who gives this process as a means of assaying the sulphuret of antimony, we obtain less of this gas by the nitro-muriatic acid than by the muriatic: this  
mani-

manifestly depends upon the circumstance that the nitric acid decomposes and burns it.

47. The same mixed acid easily attacks the sulphurated and hidro-sulphurated oxides, dissolving the oxide and separating the sulphur; sulphurated hydrogen gas is disengaged from all these solutions; but Bergman observes that that of the hidro-sulphurated oxide, made with equal parts of sulphur and of oxide, gives the greatest quantity; I shall occupy myself more in detail with this action in the subsequent numbers.

48. We do not know the action of the other acids upon antimony, its sulphuret and its sulphurated oxides; we have likewise no knowledge of that which might be exerted by the phosphoric, the fluoric, the boracic, the carbonic, or by the four metallic acids. It is even difficult to combine most of these acids by way of double attraction, with the oxide of antimony united with their acids, since, as we have seen, there are but few of these permanent solutions which can be employed for that purpose. However as water alone renders the muriatic solution turbid, which is the most permanent of all, the acids which accompany this precipitating water frequently unite with the precipitated oxide. In this manner the sulphureous acid forms a sulphite of antimony when it is poured into the muriate of this metal, not because it takes away the oxide from this acid, but because it unites with it only at the moment when the water separates it.

It

It is, therefore, probable that even in the case of double attraction, the phosphoric, fluoric, boracic, and carbonic acids may be combined with this oxide, at the moment when they are poured dissolved in water upon the muriatic solution of antimony. It will, therefore be practicable by preparing them by means of this process, to obtain and examine these antimoniated salts, which have not yet been examined, though they well deserve it.

*I. Action of the Salifiable Bases and the Salts.*

49. NONE of the earthy or alkaline salifiable bases exert any sensible action upon antimony. Its oxide only has the property of uniting with the earths during their vitrification, and of imparting to them a yellow colour, more or less of an orange cast, or approaching to the hyacinth colour. It unites in a more direct manner with the pure or caustic alkalis, which render it more soluble, and form with it a kind of crystallizable salt, soluble, and decomposable by the powerful acids; so that it then appears to act the part of an acid; we shall soon have another occasion to speak more at large concerning these salts.

50. All the alkaline substances exert a very marked action upon antimony. By means of this action, two principal medicines are prepared, which have much occupied chemists, the one under the name of Kermes mineral, the other

other under that of *fulphur auratum*. In order to understand the theory and the nature of these remarkable compounds, which form one of the most singular points in the history of antimony, I must first remark, that every pure alkaline substance, from barites to ammonia, has more or less the property of dissolving the sulphuret of antimony; that this solution, made in the dry way, and by means of fusion, forms antimoniated alkaline sulphurets; that these sulphurets decompose water with much energy; that the water which is so often united with the alkaline substances, is sufficient for converting its sulphurets into hidro-sulphurated sulphurets; that in this change, whether it be made at the very moment of the fusion, or take place only after the fusion, and be owing then to the water which is added, or to that which these compounds absorb from the atmosphere, the oxygen of the water seizes upon the antimony which it oxidates; that its hydrogen unites with a portion of sulphur, and that there results from the simultaneous combination of the oxide of antimony, of the alkaline sulphuret, and of the sulphurated hydrogen, a complicated compound, an alkaline and antimoniated hidro-sulphurated sulphuret, remaining at first in an equilibrium of composition, but soon losing this equilibrium when we attempt to dissolve it in boiling water. In this latter case, if there be a sufficient quantity of alkali, the whole is dissolved with the aid of heat; but the solution becomes

becomes turbid as it cools, and is divided into two substances, one of which deposits itself in the form of a red, or brown-red powder, which is termed in general *Kermes*, and is the hidro-sulphurated oxide of antimony; and the other, which remains dissolved, is still an alkaline and antimoniated hidro-sulphurated sulphuret, but containing a little more sulphur, and less oxide of antimony than the first of these compounds.

51. This separation into two new products, which constantly takes place in the solution of the antimoniated and hidro-sulphurated alkaline sulphuret, depends upon the circumstance, that the alkali, at least, unless it be very abundant, cannot in the cold retain all the sulphurated oxide of antimony which it holds in the heat; and that which is deposited in the form, and under the name of *Kermes mineral*, is in fact, sulphurated and hidro-sulphurated oxide of antimony. However, the portion of antimoniated sulphuret which the liquor still retains, differs from that which is spontaneously precipitated by cooling, by its containing more of sulphur and less of oxide of antimony. Thus the entire mass of this compound divides itself naturally into two different portions; the one more antimoniated and less sulphurated, which cannot be kept in solution in the cold, and which is deposited in a brown powder or in *Kermes*; the other less antimoniated and more sulphurated, which remains in solution; which

is

is separated only by the addition of the acids, with a less deep colour than the preceding, approaching more or less to the orange, and which is known by the name of Sulphur Auratum. This also may be divided into different hidro-sulphurets less and less antimoniated, and more and more sulphurated, accordingly as its precipitation is graduated, by employing only by degrees the acid necessary for separating the alkali. Hence the sulphura aurata of the first, the second and the third precipitation, less and less of an orange colour, and more and more pale, the last of which is scarcely any thing but sulphur.

It is necessary now to describe the particular action of each of these bases, or at least, of those which exert a remarkable action upon the sulphuret of antimony.

32. Barites, strontian, and lime dissolve the sulphuret of antimony sensibly, though in little abundance. It is sufficient to agitate the cold solution of these bases with this sulphuret in the state of powder for some moments, in order that these liquors when filtrated, may yield by the acids a precipitate of pale hidro-sulphurated oxide of antimony, or of sulphur auratum; but there is not a sufficient quantity of oxide of antimony formed and dissolved for real kermes to be deposited without the addition of acids. It is very evident, that by the mere contact of these alkaline or earthy solutions, a small portion of the antimony is here

always upon the same sulphuret; the three decoctions being mixed together were filtrated, and deposited by cooling a brown red powder or kermes, which was washed with water till it passed off insipid; the powder was dried, alcohol was burned upon it, and it was carefully triturated for use. This process, which is very ill-contrived, and very tedious, affords but very little kermes, at most a fortieth part of the weight of the sulphuret of antimony that has been employed. It was particularly faulty, on account of the small quantity of alkali employed, which was very far from being sufficient for the proportion of sulphuret of antimony that was taken. Accordingly, the apothecaries never followed it, when this compound became sufficiently known to be a very common medicine.

55. Lemery the younger, having claimed the discovery of this antimonial preparation, for his father, from the Academy of Sciences, his process was generally adopted and practised in the laboratories of pharmacy, where the kermes mineral was, and still is prepared in one or other of the two following ways. In the dry way, are taken sixteen parts of sulphuret of antimony, eight parts of alkali or tartar, and one part of sulphur; these three substances are well mixed by trituration; they are fused in a crucible; the mass when well fused, is poured into an iron mortar; it is coarsely pulverized when it has cooled; then boiled in a  
sufficient

sufficient quantity of water, and the liquor being filtrated through grey paper, passes clear and with a slight orange tinge, with scarcely any other smell than that of the lixivium; in proportion as it cools there separates from it a powder of a beautiful brown-red colour, or kermes, in great abundance, which is first washed in cold water, and afterwards in boiling water, then well dried, pulverized, and passed through a silk sieve.

The kermes, by the humid way, is prepared in the following manner. In twenty parts of water are boiled six parts of fixed alkali, the pure pot-ash of commerce; into the boiling liquor is thrown about one twentieth part of the weight of the alkali of pulverized sulphuret of antimony; this mixture is well agitated, it is suffered to boil for seven or eight minutes, and filtrated; the liquor deposits in cooling a large quantity of red powder, or kermes, which is well washed. By either of these processes, nearly three quarters of the weight of the sulphuret of antimony employed is obtained in kermes.

56. In both these operations, all the sulphuret of antimony treated by the alkali is not converted into kermes mineral, and it has been remarked that the residue, especially that of the humid way, contains scarcely any more sulphur, and that by fusing it in a crucible, it yields antimony almost pure. Hence it must be concluded, that the alkali dissolves the sulphur



almost entirely, and that it oxidizes only the portion of antimony which it dissolves at the same time as the sulphur. The liquors, which, in both operations, swim above the kermes mineral, or the mother waters which still contain oxide of antimony dissolved in the alkaline hidro-sulphuret, may be precipitated by the acids, which first separate from it deep-coloured hidro-sulphurated oxide of antimony, containing a large quantity of antimony, and afterwards an hidro-sulphurated oxide more and more pale, less and less antimoniated, and approaching at last to the state of sulphur. We have a proof that exactly the same series of phenomena take place as were indicated above, Nos. 50 and 51; namely, that the alkali, by dissolving the sulphuret of antimony, favours the decomposition of the water, causes its oxygen to seize the antimony which becomes oxidated in different degrees, and its hydrogen to seize a portion of the sulphur; that it retains the sulphurated and hidro-sulphurated oxide of antimony; and that it effects, by cooling, a sort of division of the products, one of which is in the state of hidro-sulphurated brown oxide of antimony, which, being furcharged with metal oxidated to the brown state, with relation to the whole mass, abandons the solution, and is deposited in the form of kermes mineral, and the other, in the state of hydrogenated sulphuret of orange-coloured oxide of antimony, remains in solution in the alkaline liquor. We have a  
proof

proof of the real existence of these phenomena, even in the property which the mother-water possesses of re-dissolving the kermes, when we heat it. But it is to be observed, that in the second precipitation which accompanies the cooling of this solution; another division is made in the hidro-sulphurated oxide of antimony, for this second precipitate has another colour, some different properties, and especially appears to contain other proportions in its principles than the first.

57. Before we were able to explain the theory of the operation of the kermes, which I have just presented, the history of the science exhibited a series of fruitless researches and labours relative to the nature of this singular compound. Geoffroy is the first chemist who has occupied himself with the analysis of the Kermes: he pretended that 72 parts were composed of 17 of metal, 14 of alkali, and 41 of sulphur. It is evident that Geoffroy had examined only ill-washed kermes; for all the chemists who since him have operated upon this substance have found no alkali in it, or have found in it only particles that had escaped from the lixiviation. Bergman, in his very interesting dissertation on the sulphurated antimonials, has committed errors, and has fallen into contradictions relative to the nature and composition of this substance, which are astonishing when we consider the ability of the author. In one place in his work (Experiment 50.) he

Z 2

says,

says, that an hundred parts of kermes have yielded him, by the muriatic acid, 0,52 of white antimonial powder, and that he could not collect more than 0,08 of sulphur, without speaking of the 0,40 of matter lost in this inaccurate analysis. It is true that he says elsewhere, that he obtained from the same weight of this compound fifteen cubic inches of sulphurated hydrogen gas; but this product does not supply the deficiency of 0,40. Besides, he affirms, that an hundred parts of kermes contain 0,52 of metal (we have just seen that these 0,52 were white oxide of antimony, and not metal), and 0,48 of sulphur: but he had said, a little before that, that he had not been able to collect more than 0,08. Hence we may conclude, that the analysis of the kermes mineral was not yet well performed by Bergman. It is known that this compound fuses into *liver of antimony*, or opaque vitreous sulphurated oxide; that, when treated by the muriatic acid, it loses its colour, affords sulphurated hydrogen gas; and that it is soluble in the alkaline sulphurets and hidro-sulphurets. Citizen Berthollet, by describing it as a hidro-sulphuret of oxide of antimony, has given a much more accurate notion of it than those which had been presented before him.

58. Citizen Thenars, in his researches concerning the oxides of antimony, has put the last hand to this work. From his analysis of different antimonial preparations compared

compared with each other, several new truths result, which, whilst they establish the first truths announced by Citizen Berthollet, give them a precision which they did not before possess. According to Citizen Thenars, kermes is only a brown oxide of antimony, united with sulphurated hydrogen, and a small quantity of sulphur. Its difference from the sulphur auratum consists less in the proportion of the substances than in the state of the oxide. In the latter, the oxide of antimony is orange-coloured instead of being brown: it is to this varied state of the oxide that these compounds owe their difference of colour. They are soluble in the alkaline hydro-sulphurets, and not in the alkalis. Finally, the kermes acts upon the air, deprives it of oxygen, analyzes it as an eudiometrical instrument, becoming pale in proportion as it is more and more oxidated, and at last it becomes white altogether. Citizen Thenars has found, by a careful and laborious analysis, for which he was obliged to re-analyze the sulphuric acid, the sulphate of barites and the sulphurated hydrogen, that kermes mineral contains.

72,760 brown oxide of antimony ;

20,298 sulphurated hydrogen ;

4,156 sulphur ;

2,786 loss in water, &c.

The Sulphur Auratum contains :

68,300 orange-coloured oxide of antimony ;

17,877 sulphurated hydrogen ;

11 to 12,000 sulphur.

These

These new results agree with the ancient experiments, the theory of which had not before been comprehended.

Kermes is prepared immediately by the mixing of a muriatic solution of antimony and of hydrogenated sulphuret, or, still better, of hidro-sulphuret of pot-ash: this mixture suddenly affords a precipitate of a brown-red colour, because as the hydrogen takes away a little oxygen from the white oxide before it precipitates it. It is also formed by exposing white oxide of antimony, wet, or steeped in water, to the contact of sulphurated hydrogen gas, and according to the same theory. As to the process by which Bergman imagined he had formed kermes, by fusing, or rather by softening together equal parts of sulphur and of oxide of antimony, prepared by nitre (No. 29.) it is very evident that this is not a real kermes; for it does not contain a sufficient quantity of hidro-sulphuret to constitute it such: it is only a fused sulphurated oxide of antimony.

59. What I have here explained concerning the *hidro-sulphurated brown oxide of antimony*, or *kermes*, of which I have been obliged to modify the first denomination of the methodical nomenclature, on account of the discoveries of Citizens Berthollet and Thenars, relative to the presence of sulphurated hydrogen, and of the different oxides of antimony, which determine its real nature, proves, that in order to make an exact analysis, it was necessary,

necessary, after having estimated the proportion of sulphurated hydrogen that is disengaged from it by the action of the acids, to determine that of the sulphur, by burning it completely by means of the nitric or oxygenated muriatic acid, and by precipitating the sulphuric acid thus formed by the nitrate or muriate of barites, and that of the oxide of antimony, by dissolving it in the muriatic acid, and precipitating it with water. I must also observe on this occasion, that the acids cannot serve to analyze the hidro-sulphurated oxide of antimony by simply separating the sulphur, and dissolving its oxide, as has been believed; for in this operation, the sulphur always retains a portion of oxide of antimony. I must, moreover, observe, that this hidro-sulphurated oxide does not yield sulphurated hydrogen gas by the action of fire, and that its hidro-sulphuret appears to be decomposed during its fusion into vitreous sulphurated oxide. Finally, I shall remark, that there appear to be different hidro-sulphurated oxides of antimony, varying in the proportion of their principles, according to a multitude of different circumstances that accompany their formation.

60. When the nature of these *hidro-sulphurated oxides of antimony* has been well comprehended, that of the sulphur auratum will be equally comprehended. Being more soluble in the alkaline sulphurets than the first, they are separated and obtained from them only by decomposing

posing their solutions by the acids: they contain more sulphur, less oxide of antimony, and this oxide less oxidized than the kermes; they vary amongst themselves according to the mode of their preparation, and the proportions of their principles are very different. In order to obtain a constant proportion, Goetling has proposed the following process: mix well two parts of sulphuret of antimony, reduced to a very fine powder, with three parts of sulphur; dissolve them in a boiling ley of caustic alkali; filtrate, dilute the solution with water, precipitate it by the diluted sulphuric acid: in this manner are obtained nearly  $4\frac{1}{2}$  parts of an hydrosulphurated sulphuret of antimony, similar to that which is obtained by the third precipitation of the mother waters of the hydrosulphurated brown oxide of antimony. Bergman observes justly concerning this process, that it is preferable to that which is generally practised in order to obtain it; that the proportion of its principles may also be varied, according to that of the sulphur which is added at the option of the physician, who will then know what he shall positively employ.

61. I shall conclude this account of the properties of the sulphurated and hydrosulphurated oxides of antimony, by observing, that these compounds, whether we form them by immediate fusion with the metallic oxide and the sulphur, or obtain them by the immediate union of the antimoniated solutions with the alkaline hydrosulphurets,

phurets, or whether they be the product of the action of the muriatic acid upon the sulphuret of antimony, or that of the action of the alkalis, always show a more feeble adhesion, a less intimate combination between the molecules of the oxide of antimony and the molecules of sulphur, than there exists in the sulphuret of antimony; for these substances are more decomposable, since merely a long exposure to the air is sufficient to alter them, and they assume the vitreous character in the fire. The presence of the sulphurated hydrogen which brings them to the state of sulphurated hidro-sulphurets, and of triple compounds, is the cause of this smaller adhesion between their molecules, as the frequently larger proportion of sulphur is its effect.

62. Amongst the salts there is no class which is not susceptible of being in some measure altered by antimony and its sulphuret, and which does not at the same time change the nature of these bodies. Monnet is the first who has described the action of antimony upon the sulphates of pot-ash. By fusing in a crucible one part of this salt, and half a part of antimony, the metal disappeared; a mass is obtained, seemingly vitrified or fritted, and caustic, which is an antimoniated sulphuret of pot-ash, and which, when diffused in hot water, yields hidro-sulphurated oxide of antimony by cooling. The antimony has, therefore, taken oxygen from the sulphuric acid, and has united  
in



in the state of oxide with the sulphuret of pot-ash which has been formed. The contact of the water, by its decomposition, has quickly hidro-sulphurated this antimoniated alkaline sulphuret; so that its hot solution has become susceptible of separating itself into two portions; the one highly antimoniated, which is spontaneously precipitated in the brown state; the other more sulphurated, which has remained dissolved. There is no room to doubt that most of the sulphates, and even of the earthy and alkaline sulphites, would experience the same change from the action of antimony. The sulphuret and pure oxide of this metal, on the contrary, produce no kind of alteration upon them.

63. The nitrates are all capable of burning antimony and its sulphuret, by heat, or in a red heat, more or less violently and, completely, according to the quantity of them that is employed. This action has been made use of in order to prepare, with the aid of the nitrate of pot-ash, the species of the genus which is preferred, as we have seen upon a former occasion, a great number of different antimoniated preparations, of which I shall here mention the principal. A mixture of two or three parts of this salt, and one part of fine powder of antimony, well pounded in a mortar, detonates strongly whether we place it in contact with ignited combustible substances, or throw it into a red-hot crucible, or heat it

it to redness in a close crucible. This latter method is preferable to the two first, which, by admitting the contact of the air, occasion a loss of a great part of the product of the operation, for it is known that antimony is volatilized by a strong heat. The detonation is accompanied with a very lively white flame; the antimony is strongly and completely oxidized by the oxygen of the nitre, which is itself decomposed and reduced to its alkaline base. The residue of this detonation is a white mass, scorified, which, when washed with water, leaves a portion of the oxide of antimony united with a small portion of pot-ash, and gives another combined with much more alkali, and dissolved like a species of salt, in which the oxide seems to perform the function of an acid. The oxide prepared in this manner was formerly termed *diaphoretic antimony by the regulus*. The undissolved portion of oxide of antimony was considered as a pure oxide; but Citizen Tennant has discovered that it retains a portion of pot-ash which constitutes about a fifth of it, and that, in consequence, the product of the detonation of the nitre and of the antimony, is divided into two parts by washing; namely, into a species of antimoniated pot-ash which is dissolved, and a sort of insoluble antimonite of pot-ash.

64. This preparation is more frequently made with the sulphuret of antimony than with the metal, because, as has already been so often remarked, this sulphuret has been much  
more

more employed than the metal itself. Three parts of nitre, and one of sulphuret of antimony, well triturated together, placed in an iron mortar, and touched with an ignited coal, inflame and continue to burn with emission of sparks, much activity, and very abundant white vapours, till the mixture is entirely converted into a mass of a yellowish colour, half-fused or scorified, which retains for some time the redness of the ignition, and cools slowly. The quantity of nitre which is employed in this experiment, and the force of the combustion which it excites on account of the proportion of oxygen, burns the sulphur and changes it into acid, as also the antimony which is found completely oxidated. The product consists of sulphate of pot-ash, a little nitre escaped from the detonation, oxide of antimony united with the pot-ash; and it is susceptible of being divided into two compounds by the action of water, as is done with the product of the combustion of pure antimony by nitre. This mass was termed in Pharmacy, *solvent of Rotrou*, or *diaphoretic antimony not washed*. When it is thrown into hot water, it dilutes; the salts and a part of the oxide, united with the pot-ash, dissolve in it; the greater part of the oxide combined with one fifth of pot-ash, remains at the bottom of the water, in a white, insoluble and almost insipid powder. After it has been well washed and cleaned, it is formed into masses, dried, and kept under the name of *washed diaphoretic antimony*. The  
water

water of the lixiviation, which, besides the nitre which is not decomposed, but reduced to the state of nitrite, and the sulphate of pot-ash, contains still a portion of oxide of antimony united with this alkali in the state of a salt, may be decomposed by the acids, which form in it a precipitate of white oxide, termed *ceruss of antimony*, or *pearly matter of Kerkringius*, because it was known, and well described by this last Commentator on the Treatise of Basil Valentin. Formerly the liquor that swam above this precipitate was evaporated; and the salt which was obtained from it, containing undecomposed nitre, sulphate of pot-ash, and the new salt formed by the precipitating acid combined with the pot-ash, however different it was, as all the acids could be employed for this precipitation, bore the improper name of *antimoniated nitre of Stahl*: but it is evident that, even when prepared by the nitric acid, it does not contain oxide of antimony, if its preparation has been well conducted.

65. I have already announced (No. 49,) that the oxide of antimony unites with the alkalis; and we have just seen a more direct proof of it, both in the undissolved part of this oxide, and in the lixiviation of the product of the detonation of antimony, and the sulphuret of antimony with nitre. This lixivium contains a species of salt formed by the union of part of the oxide with the pot-ash; a salt which might be named *antimonite of pot-ash*, since,  
according

according to the observation of Citizen Berthollet, it is susceptible of crystallizing; it possesses a determinate degree of solubility; it is decomposed by the acids. As to the rest, I speak under in a particular number, only in order to call the attention of chemists to the singular combinations of this acidiform oxide with the bases, and to induce them to make new inquiries relative to these combinations which have as yet been only surmised. In general, the oxide of antimony made by nitre, or by the decomposition of nitric acid, appears to be more oxidated, and more approaching to the state of acid, than that which is obtained by the simple combustion of antimony fused in the air. It was with the oxide prepared by means of nitre, that Bergman made his sulphurated preparations; it was by endeavouring to reduce it with soap, that Geoffroy discovered that pyrophorus burning like a fire-work, which I have already mentioned, (No. 23). Lastly, this oxide of antimony, which is the most oxygenated of all, has been carefully examined by Citizen Thenars, who has found it to contain 0,32 of oxygen. The principal characters which he has discovered in it are, that it is the least soluble in water of all the oxides of antimony, that it unites with the acids with the greatest difficulty, that it requires for its difoxidation the highest temperature, without being irreducible, as was formerly believed, that it cannot be well reduced unless when it is heated

heated with a portion of antimony, which, by sharing its oxygen which it takes away by degrees, causes it to pass again through all the successive degrees of oxidation; namely, from the white to the yellow, from the yellow to the orange-coloured, from the orange-coloured to the brown, and from the brown to the black.

66. If instead of employing three parts of nitre, and one part of sulphuret of antimony, we employ only equal parts of these two substances, we obtain by the action of the fire an opaque vitrification, which has been termed *Liver of Antimony*. Bergman observes, what may apply to all these cases of the combustion of the sulphuret of antimony by nitre, that when we throw the materials at several times into a red-hot and open crucible, we may lose nearly half the mixture; he, therefore, advises us to put the substance into a cold crucible, to close it, and to apply the fire till it is fused. By this process scarcely more than an hundredth is lost. The same method is to be recommended for all the preparations which are made with nitre and antimony, or its sulphuret. We thus obtain, under some scoria, an opaque well-fused glass of a deep brown colour, which is a real oxide of antimony, brown, sulphurated and hidro-sulphurated, vitrified, which was formerly termed *liver of antimony*, on account of its colour and opacity, to distinguish it from the *glass of antimony*, which is transparent and of a hyacinth colour. We see that here the pro-  
4 portion

portion of the nitre is not sufficient to burn the whole of the sulphur; we see also that the antimony burns before the sulphur, as takes place in the preparation of the kermes. This liver of antimony, or antimoniated sulphuret of pot-ash, contains a small quantity of sulphite and of nitrate of pot-ash, which Bergman believes to be the true *antimoniated nitre* of Stahl. He remarks also, that these salts prevent the deliquescence which the antimoniated sulphuret formed simply with equal parts of fixed alkali, and of sulphuret of antimony fused together, undergoes.

It is easily conceived from what has already been said, that when this vitreous product is washed, the water, by taking up the salts, dissolves also a portion of hidro-sulphurated oxide of antimony, will deposit by cooling a portion of real kermes, and afford by the acids hidro-sulphurated orange-coloured oxide, or sulphur auratum. The undissolved portion of the *liver of antimony*, well washed and reduced to powder, was termed *Crocus*, or *Saffron of Metals*, on account of its deep orange-red colour. Bergman considers it as a species of kermes or hidro-sulphurated oxide of antimony; it yields sulphurated hydrogen gas by the muriatic acid; and though it has not been subjected to an accurate analysis compared with that of the kermes strictly so called, it is evident, that it differs from it only by a larger proportion of oxide of antimony, and also by its

its more advanced state of oxidation: it is likewise more active, more purgative and more emetic, on which account it is employed as a medicine for horses. The scoria that is situated above the liver of antimony, is grey, and yields by lixiviation a crystallized salt, which is fused, swells with a noise before the blow-pipe, and presents a species of detonation; it remains red or yellow for some time after its cooling, but its colour disappears after some time. This salt yields sulphurated hydrogen gas with much froth by the contact of the acids; and when fused afterwards with the blow-pipe upon a coal, it is absorbed and leaves only a white circular trace in the place which it occupied. Bergman concludes from these experiments, that the salt of the scoria of the liver of antimony is a mixture of nitre and of sulphite of pot-ash, with some traces of oxide of antimony. He adds that these scorias yield sulphurated hydrogen gas by the muriatic acid, before as well as after their being washed; but that they do not deposit any hidro-sulphurated oxide of antimony.

67. It will be recollected, that by treating eight parts of sulphuret of antimony with six parts of tartar and three of nitre, we obtain antimony, because the small portion of oxygen of the nitre is employed to burn the tartar, to reduce it into a coal, which prevents the oxidation of the metal, and to burn a small quantity of sulphur, of which the larger part combines



with the pot-ash, the base of the nitre, and of the tartar, (see No. 14). The scoria which float above the metal, and which are very abundant and very voluminous, are much compounded. We find in them antimoniated sulphuret of pot-ash, which, when washed with hot water, acts in perfectly the same manner as the lixivium afforded by the kermes mineral and the sulphur auratum. It is mixed with sulphate and sulphite of pot-ash, and much carbon. It is, therefore evident, that the antimony is not completely disengaged by this process, which is to be considered merely as an imperfect assay of its ore, since a portion, and even a pretty considerable one, remains oxidated and combined with the very abundant pot-ash of the scoria.

68. Antimony appears to be capable of decomposing the muriate of soda, according to Citizen Monnet, who asserts that when we heat a mixture of these two bodies in a retort, sublimed muriate of antimony is obtained; but this chemist does not speak of the residue, which he does not seem to have examined, and which ought to contain soda, if the salt has been really decomposed. The antimony does not act upon the ammoniacal muriate, as Bucquet has convinced himself, and it yields neither ammonia nor muriate of antimony when it is distilled with this salt, as Juncker had, however, advanced.

69. It

69. It appears that the sulphuret of antimony acts more upon the muriates, than the metal does, on account of the attraction of the sulphur for the bases of these salts. Thus by distilling a mixture of this sulphuret with muriate of ammonia, we obtain, according to several chemists, a purple pulverulent sublimate, which can only be an ammoniaco-antimonial hidro-sulphuret. This experiment deserves to be repeated with care.

70. The super-oxygenated muriate of pot-ash, the only one of this genus which is well known and employed, acts very powerfully upon antimony and its sulphuret; mixed in the proportion of two parts to one of these combustible bodies, and inflamed by the contact of a body in the state of combustion, it causes them to burn with such great activity, that the whole is dissipated in the air in a white vapour, leaving only a slight circular mark upon the body on which this mixture has been placed. When this experiment is performed in a close vessel, we obtain from the antimony a white oxide, which is separated from the muriate of pot-ash by the action of water, which dissolves the latter; by this means we obtain the oxide perfectly pure and insulated. When a sudden stroke is given to the same mixture of sulphuret of antimony, or antimony and super-oxygenated muriate of pot-ash, upon a steel anvil, it fulminates with a loud report, emitting a flame as brilliant and rapid as lightning.

71. Formerly, two antimoniated vitreous compounds were prepared in the pharmaceutical laboratories; the one, known by the name of *Ruby of Antimony*, or *Opaline Magnesia*, was produced by the fusion of equal parts of decrepitated muriate of soda, nitrate of pot-ash, and sulphuret of antimony; in this manner, a vitriform mass was obtained, of a light brown colour, brilliant and covered with a white scoria. The other preparation, very improperly termed medicinal regulus, was prepared by the fusion of a mixture of fifteen parts of sulphuret of antimony, twelve parts of decrepitated muriate of soda, and three parts of tartar. In this manner was produced a black glass, shining, opaque, without the metallic aspect, and very dense. These two compounds are species of liver of antimony, which proceed from a decomposition of the muriate of soda, or of nitrate of pot-ash, and have not yet been examined.

72. The reciprocal action of antimony, of its sulphuret and of its oxides upon the phosphates, the fluates, the borates, and the carbonates has not been appreciated; we only know that the phosphates and the borates, fused with the white oxide of antimony, become vitrified and assume the brown or the hyacinth colour, and that the carbonates heated with the sulphuret of antimony lose their carbonic acid, effervesce at the moment when they combine with its sulphur, and afterwards form antimoniated

moniated sulphurets, which contain the alkalis in the caustic state.

73. Scheele has found in the combined action of the salts and of the acids a very simple and very commodious process, for procuring abundantly and easily that species of oxide of antimony, which water always separates from its muriatic solution, and which is known by the name of Powder of Algaroth, as I shall show in the article concerning mercury. In this process, a liver of antimony is prepared by treating by detonation a mixture of one part of sulphuret of antimony, and a part and a half of nitre. One part of this compound is mixed with three parts of water, and nearly one part of sulphuric acid, to which muriate of soda is added in the same proportion as this acid. This mixture, placed in a matrafs, is left to digest for twelve hours upon a sand-bath, the vessel being constantly agitated. When the solution has been made, and has cooled, it is passed through a piece of linen; the undissolved residue is treated again with the same solvent, diluted sulphuric acid, and muriate of soda, and the liquor, after having been filtrated, is mixed with the first. When this liquor is poured into boiling water, a precipitate is formed of white oxide of antimony, or *powder of Algaroth*, which is to be washed in a large quantity of water, and dried for use. In this operation, the muriatic acid, disengaged by the sulphuric, dissolves the oxide contained in

in the *liver of antimony*, and the water that is added precipitates it.

K. *Uses.*

74. It has been seen elsewhere, that the numerous labours of the chemists upon the sulphuret of antimony were undertaken with the view to prepare medicines of a great degree of activity, and exempt from the inconveniences that were apprehended in this substance. Of all the preparations that have been successively invented, there is scarce any which is still employed for medical use, except the *kermes*, the *antimonium diaphoreticum*, the *sulphur auratum*, and the *glass of antimony*. The use of antimony in pills, or as a medical cup has been laid aside, because their effects have been found to be very variable and uncertain. Several other preparations which shall be elsewhere mentioned are also used as medicines. In general, the antimonials are emetic, purgative, sudorific, and pectoral. Many physicians doubt the efficacy of the sulphur of antimony suspended in ptisans and decoctions, to which it was long believed that it communicated a sudorific and attenuating property. The powder of Chevalleraie, or the oxide of antimony by nitre, treated seven successive times with this salt, and lixiviated each time, has long since been laid aside, as being destitute of any virtues, and too much oxidated; for it is at present sufficiently ascertained,

tained, that antimony in its metallic state has no virtues, that it assumes more or less powerful properties when it is combined with a certain proportion of oxygen, and that it loses them again when it contains a very large quantity. The effects of antimonial medicines are very much exalted, either by the medium state of oxidation into the brown, orange, or yellow colour, or by the combination of these oxides with sulphur and sulphurated hydrogen, as is seen in the sulphurated and hidro-sulphurated oxides of antimony, which are known by the appellations of *kermès* and *sulphur auratum*, and which are the most active preparations of this metal.

75. Antimony is used in many of the arts: it is the base of the alloy which is employed for casting printing-types, to which it communicates hardness. It is often made to enter, with lead and tin, into rigid hard alloys, which are very useful for a variety of purposes. The oxide of antimony is used in the fabrication of coloured glass, enamels, the glazing and painting upon porcelain; it is the basis of the yellow, brownish, and orange colours, and shades more or less approaching to that of the amethyst. It is mixed with several other different oxides, in order to produce a great variety of colours, the effects of which have been observed, but their causes not yet sufficiently appreciated.

## ARTICLE XIII.

*Of Tellurium.**A. History.*

1. MR. KLAPROTH of Berlin, to whom we owe the discovery of Titanium and Uranium, has given the Latin name of *Tellurium*, which I render (in French) by the word *Tellure*, to a brittle metal which he discovered in the beginning of the sixth year of the Republic, (end of the year 1797,) and made known to the scientific world, at the public sitting of the academy of Berlin, in Nivose of the same year, (January 25, 1798). This appellation was adopted in consequence of those which he had given to the two metals already mentioned. Like those, it is borrowed from fabulous mythology. It were to have been wished that this celebrated Prussian chemist had derived it from some characteristic property of this new metal, as we have done in adopting the appellation of chrome for the metal discovered by Vauquelin.

2. He made this important discovery in examining the gold ore of Muriahilf, of the mountains of Fatzbay in Transylvania, known by the name of the white ore of gold, *aurum paradoxum*, *aurum problematicum*. Already in the year 1782, Mr. Muller of Reichenstein, had suspected the existence of a peculiar metal in this ore. Bergman, to whom this mineralogist

logist had sent a specimen of the ore, had not been able, on account of the small quantity of it with which he was provided, to decide whether it was really a peculiar metal, or merely antimony, with which it has some remarkable similarities; but he was more inclined to the former opinion.

3. After having treated this ore with the nitro-muriatic acid, Mr. Klaproth precipitated and re-dissolved it by means of pot-ash, and afterwards separated it again with muriatic acid. The substance separated from the alkali, and deposited by the last-mentioned acid, having been heated with an oil, yielded the metal which he has termed Tellurium. This discovery has not yet been since confirmed by other chemists, as the minerals in which Mr. Klaproth found the Tellurium are yet very rare; however, the talents and accuracy of this illustrious chemist are sufficiently known to authorize our confidence in the facts which he announces.

#### *B. Physical Properties.*

4. TELLURIUM is of a white colour, approaching to a lead-grey, and possesses a considerable degree of metallic lustre. It is very brittle, and easily reduced into powder. Its texture is lamellated like that of antimony. By slow refrigeration it assumes a crystalline and regular form, especially at its surface. Its specific gravity is 6,115.

5. It



assay of the ore of Fatzbay, by means of which he not only extracted the tellurium, but also separated it from other substances that were combined with it, so as to make an exact analysis of the mineral in which the tellurium is contained. It is necessary that I should here describe his process, in order that it may be repeated by those chemists who may have similar ores in their possession.

12. By slightly heating the ore with six parts of muriatic acid, and subsequently boiling it, after having added to it three parts of nitric acid, a considerable effervescence took place, and the whole was dissolved. The solution diluted with a little distilled water, was mixed with a sufficient quantity of caustic ley of pot-ash to dissolve the precipitate; nothing more remained than a brown flaky deposit, consisting of oxide of gold and oxide of iron. The alkaline solution of oxide of tellurium was mixed with muriatic acid, so as to saturate the pot-ash, and a very heavy white powder was deposited in great abundance. It was by reducing this powder to the consistence of a paste with a fat oil, and afterwards heating it to redness in a glass retort, that Mr. Klaproth obtained the tellurium reduced, partly fused and crystallized at its surface at the bottom of the retort, and partly sublimed and fixed in drops at the curvature of the vessel.

13. The same experiment, performed upon the three other ores, the graphic gold, and the two of Nagyag, and combined with the processes

for separating the different substances with the tellurium in them, gave Mr. Klaproth the following results relative to the composition of these ores.

The Ore of Fatzbay, <i>Aurum Problematicum</i> contains, according to analysis - - - - -	{	Tellurium - - -	925,5
		Iron - - -	72,0
		Gold - - -	2,5
			<hr/> 1000,0

The graphic gold of Sylvania - - - - -	{	Tellurium - - -	60
		Gold - - -	30
		Silver - - -	10
			<hr/> 100

The yellow gold ore of - - - - -	{	Tellurium - - -	45
		Gold - - -	27
		Lead - - -	19,5
		Silver - - -	8,5
		Sulphur, an atom.	
			<hr/> 100,0

The foliated grey ore of Nagyag - - - - -	{	Lead - - -	50
		Tellurium - - -	33
		Gold - - -	8,5
		Sulphur - - -	7,5
		Silver and Copper	1

Nothing can yet be said concerning the purity of the ores of tellurium, as no one has hitherto endeavoured to extract this from them, and they have only been analysed with the view to separate the gold.

*E. Oxidability by the Air.*

15. WHEN we heat tellurium with the blow-pipe upon a piece of charcoal, it burns, after having been fused, with a pretty lively flame, of a blue colour, edged with a greenish tinge; it is entirely volatilized in the form of a smoke of a whitish grey colour, which diffuses a peculiar fetid odour, that Mr. Klaproth compares to that of radishes.

16. The oxide of tellurium appears to be extremely fusible, for nothing more is required than to heat it in a retort, in order to obtain from it a mass of a straw-yellow, which exhibits a radiated texture when it has cooled. It is reduced rapidly, and with a kind of explosion resembling a detonation, when it is heated in a hole made in charcoal, and surrounded with this substance.

*F. Combination with the Combustible Bodies.*

17. MR. KLAPROTH has only pointed out the combinations of tellurium with sulphur and with mercury; and the latter combination is merely indicated by its easily forming an amalgam. It appears to form with sulphur, and undoubtedly by fusion, a grey sulphuret of lead of a radiated texture and readily crystallizable.

*G. Action upon Water and the Oxides.*

18. WE find no information in the memoir of the chemist of Berlin concerning the habits of tellurium with respect to water, and the metallic oxides. However, amongst the facts which he has described, there are several which prove that its attraction for oxygen is but weak: hence we may presume that it cannot exert any action upon water, nor a great number of metallic oxides, since its own is so easy to be decomposed, as I have already mentioned, and as I shall further show in considering the rest of its properties of which I shall have occasion to treat.

*H. Action upon the Acids.*

19. TELLURIUM seems to be very susceptible of being attacked by most of the acids: the information which its discoverer has given us respecting its union with these burned substances, is the following. One part of Tellurium mixed in the cold with one hundred parts of concentrated sulphuric acid, in a close vessel, causes this acid to assume a fine crimson colour. On adding water, drop by drop to this solution, the colour disappears, and the small quantity of dissolved metal is deposited in the form of black flakes. The same solution, when heated, equally loses its colour, and gradually precipitates

tates the oxide of tellurium in a white powder. When on the contrary we employ sulphuric acid diluted with two or three parts of water, and with the addition of a small quantity of nitric acid, this mixed acid dissolves a pretty considerable quantity of tellurium; the solution is clear and colourless, and is not decomposed by a larger quantity of water. The form and other properties of this sulphate of tellurium are not known.

20. The nitric acid easily dissolves tellurium; this solution is white and considerably transparent. When concentrated, it spontaneously yields small crystals of a white colour, light, and in the form of needles aggregated in dendritic figures. The nitro-muriatic acid also dissolves it very easily; a large quantity of water added to this nitro-muriatic solution, precipitates the oxide of tellurium in the form of a white powder, which is soluble in the muriatic acid. Mr. Klaproth has given no account of the action of this last acid upon the metallic tellurium.

21. All the pure alkalis precipitate the acid solutions of tellurium in a white oxide, soluble in the acids; an excess of alkali re-dissolves the whole of the precipitate; it is separated again by means of the acids, employed with caution. If, instead of pure alkali, we make use of an alkaline carbonate, we likewise obtain a precipitate, but one which is much less soluble in an excess of the precipitant.

22. The

22. The alkaline sulphurets, added to the acid solutions of tellurium, form in it a precipitate of a brown or blackish colour, accordingly as the metal in the solution is more or less abundantly oxygenated. Sometimes this precipitate resembles the hidro-sulphurated brown or orange-coloured oxides of antimony; or the *Kermes* and the *Sulphur Auratum*; this is one of the analogies which subsist between tellurium and antimony. The sulphurated or hidro-sulphurated oxide of tellurium thus formed, when laid upon a red-hot piece of charcoal, burns with a small blue flame, and is volatilized into a white smoke.

23. The infusion of galls, poured into the acid solutions of tellurium, causes them to deposit a flaky precipitate, of a dull yellow colour. The prussiate of pot-ash, in a state of considerable purity, does not precipitate them; in this very remarkable property tellurium resembles antimony, gold, and platina; besides these four, there is no other metal which is not precipitated, or the acid solutions of which are not decomposed, by the prussiate of pot-ash.

24. Zinc and iron separate tellurium from its acid solutions, in the metallic state, and in the form of small black flakes, fusible into a metallic button upon burning charcoal, and which resume their lustre by mere friction. Antimony presents the same precipitation with the liquid nitrate and sulphate of tellurium, a convincing proof that these two metals are really very dif-

ferent from each other. Tin possesses the same property, with respect to the new metal; its muriatic solution, mixed with that of tellurium in the same acid, gives a black metallic precipitate.

25. The oxides of tellurium, precipitated from its acid solutions by means of the alkalis, or from its alkaline solutions by means of the acids, are very easily reducible by charcoal, and in this reduction they lose their oxygen so quickly, that they exhibit, during the operation, a motion and rapidity that may be compared with a detonation. It is sufficient to mix them with fatty substances, and heat them in a retort, in order to obtain them in the state of metallic tellurium, partly fused and collected in a button at the bottom of the vessel, and partly sublimed into solid drops at its curvature.

#### *I. Action upon the Bases and the Salts.*

26. MR. KLAEPROTH has said nothing concerning the action of tellurium upon the earthy and alkaline bases. It only results from his first experiments, that the oxide of this metal is easily soluble in the liquid caustic alkalis. The spontaneous fusibility of this oxide authorizes us to believe, that it may enter with the earths into vitrification, and that it is capable of imparting to the glass a straw-yellow colour.

27. Its

27. Its easy combustibility affords equal reason to believe that it may be speedily burned by the nitrate of pot-ash, and by the super-oxygenated muriate of the same base. There is no doubt, that when mixed in the state of powder with the last mentioned salt, it will inflame and fulminate by percussion, as is the case with so many other metallic substances.

K. *Uses.*

28. NOTHING can be yet said concerning the uses of a metal so recently discovered, and which appears hitherto to be so scarce. But should it be found in other ores besides those of Transylvania, as there is reason to hope may be the case, it cannot be doubted that it may become of great utility in the arts, as appears from its extreme fusibility and its slight adhesion with oxygen. Before I conclude this article, I cannot refrain from remarking how important an acquisition science has made, in the discovery of a metal, which seems to hold a middle rank between antimony and mercury, which is very easy to be fused, and which is obtained with such facility from its ores; and how much superior advantages its discovery promises to mankind, than those of uranium and titanium, which we owe to the same chemist, but the treatment of which is so difficult, and their reductibility and fusibility so limited.



## ARTICLE XIV.

*Of Mercury.**A. History.*

1. MERCURY, which, like many other metals, appears to have received its name from the planet with which it was compared by the Persians, on account of its nature which was supposed to approach to that of gold, as this planet is nearest to the sun, has been known since the most remote ages of antiquity. From a comparison of its properties with those of silver, it was long ago termed *quick-silver*, *hydrargyrum*. In the species of hieroglyphics that were formerly employed for representing bodies, mercury was represented by the combined signs of the sun and moon, or of gold and silver, linked together and supported upon a cross. The sign of the gold was placed in the middle, and over it was seen that of the silver, which seemed to cover and colour the first; the cross at the bottom signified that it possessed acrimony. Its use in the arts bears date from a very remote antiquity.

2. The alchemists have laboured much upon this metal. They considered it as very much resembling gold and silver, and differing but very little from them; they imagined that it wanted but very little to become either the

one

one or the other, and they always hoped to discover the means of transmuting it into these metals. Some of them have even affirmed, that they had succeeded in effecting this transmutation. These adepts agree with each other, that it is much more easy to convert it into silver than into gold. According to them, in order to convert it into silver, nothing more is required than to fix it. It was, therefore, in this fixation of mercury that they made all the art of their opus magnum, all the marvellous of their science to consist; this was the grand object of their attention, and the scope of all their wishes. All these pretensions, however, are not supported by a single well-attested fact; and the more we advance in the study of the properties of mercury, the more differences we find between it and the metals to which it has been supposed to approach the nearest.

3. To these opinions, exaggerated and hypothetical as every thing belonging to the pretended art of alchemy is, the adepts added another still more absurd and ridiculous. By tormenting this metal in a thousand ways, and considering it as the first and most important object of their researches, they were led to such a pitch of extravagance, as to pretend that mercury was a principle of all beings, that it was one of the elements of Nature, which she employed in the composition of many substances; that it was contained in all metals; hence they distinguished two species of mercury



cūry, that of the philosophers, the principle of a great number of substances, which they pretended exclusively to know how to extract, and to possess; and the other, the common mercury, the mercury of all the world, that which is employed in the arts. Hence arose the hypothesis of the *mercurial principle*, or of the *mercurial earth*, which Becher has distinguished from the other earths, and which he supposed to exist in all substances that are at the same time ponderous and volatile. It will readily be believed, that no chemist has been able to demonstrate this pretended earth.

4. Who would imagine that these extravagant notions and hypotheses, destitute of all foundation, have, nevertheless, given birth to the chemical history of mercury? who should conceive that it is to the toilsome researches of these unfortunate and indefatigable labourers in an art which never existed, that we owe the first and most arduous discoveries that have been made upon this beautiful metal? Nothing, however, can be better demonstrated than that such is really the case. It is to the alchemist that we owe our knowledge of the volatility of mercury, the art of knowing and obtaining it in a state of purity, the knowledge of its unalterability in close vessels, of its oxidation by fire and air, of the processes required in order to make it burn by preventing its diffusing itself in the air, of its principal combinations, of the immense variety of colours of its precipitates,

pitates, of its salts, and their different states, of its action upon metals, of its union with sulphur, and in a word, of its principal properties.

5. The chemical physicians, on their part, always influenced by the idea of appropriating natural bodies to the treatment of diseases, of diminishing the acrimony of those that were too active, of directing their effects, &c. have performed a multiplicity of operations upon mercury and its pharmaceutical preparations. They have discovered in it a great number of properties, have made it enter into a variety of different compositions, and have greatly advanced our knowledge of the attractions to which it owes all the modifications it is capable of receiving.

6. The most celebrated philosophers, and the most able chemists, have all successively occupied themselves with this metal; they have endeavoured to ascertain all its properties with more or less precision; and the use which has been made of it since the end of the last century, or since the time of Boyle, in the construction of a great number of philosophical instruments, has afforded frequent occasion for investigating and examining its different characters. It is in this manner that its weight, its phosphorescence, its dilatibility, its volatility, its alterability, its mobility, &c. have been successively ascertained.

7. It

the properties of mercury, which, besides is one of the most useful of metallic substances for medicinal purposes, for the arts, and for all those branches of knowledge, the improvement of which tends to accelerate that of human reason in general.

*B. Physical Properties.*

9. **MERCURY**, a metal which is always fluid when in a pure state, at the surface and in the interior of the globe, is one of the most brilliant and shining of all known metals; when its surface is sufficiently clear, it forms a very fine mirror. Its colour is as beautiful as that of silver, with which it has always been compared. After platina and gold, it is considered as the heaviest of all known bodies. Its specific weight is 13,568, taking water at 1,000. Citizen Guyton, however, places the tungsten metal above it, to which he ascribes a weight equal to 17,600. Muschenbroeck has reckoned that of mercury from 13,500 to 14,110, according to its different degrees of purity. Formerly also authors were very particular in observing, that all the most ponderous substances swam upon its surface, whilst gold alone sunk in it; at the present day we have to add to this, platina and tungsten.

10. The divisibility of this liquid metal into an immense number of small globules, by means of pressure, has attracted the attention  
of

of all the natural philosophers who have occupied themselves with it. Boyle, after having reduced it to a state of extreme division by distillation, receiving it into a large capital of glass, the inner surface of which it covered with an innumerable quantity of globules, discovered them to be as many small spheres or mirrors, which, collected upon the glass, gave it a very bright white colour. The manner in which it passes, by pressure, through the pores of prepared skins, and its falling down in a silver-shower, also prove its extreme divisibility, which is likewise apparent from the ill effects which its vapour produces upon persons who remain for some time exposed to it. Liebknecht tells us that by striking a globule of mercury six lines in diameter, he divided it into such extremely minute globules, that he could perceive 100,000,000 of them with the aid of the microscope.

11. It is not surprising that a metal which is always fluid, of great ponderosity, of perfect brilliancy, and at the same time singularly volatile, so useful in a great number of the arts, so remarkable, and so different from all other metals in its combinations and chemical properties, has been considered as a kind of independent body, an anomalous substance, and even as a sort of principle, capable of communicating to other bodies a part of its characteristic properties. It was the water which does not wet, *aqua non madefaciens manus*, of some authors,

thors, the movable silver, *argentum mobile*, of some of the ancients; appellations of which the word *quick-silver* is probably a translation. It was supposed to be a powerful agent in the operations of nature, as it appeared to be so important an agent in the operations of art.

12. Nevertheless, too much stress has been laid, in the singular notions and the exaggerated pretensions of the alchemists, upon the fluidity of mercury, as upon an indelible property. Boerhaave still asserted in his Elements of Chemistry, that mercury could not be rendered solid by any degree of cold, though he admits a condensation of  $\frac{1}{11}$  of its primitive volume; a circumstance which cannot take place in its real congelation. This assertion of Boerhaave and other philosophers who have followed him, was proved to be false in the year 1759; in which year the academicians of Petersburg, availing themselves of an intense degree of natural cold, augmented it still further by a mixture of snow and fuming nitrous acid: the mercurial thermometer which they used descended to 213 degrees of DeLisle's scale, which corresponds with 46—0 of that of Reaumur. As the mercury did not descend any lower, but seemed stationary, the academicians broke the glass bulb of their instrument, in which they found congealed mercury, that formed a solid substance susceptible of being extended by the hammer. They thus discovered that mercury might become solid, and that in this state

state it possessed a certain degree of ductility. They remarked that at every stroke of the hammer, the pressure, developing the caloric in the interior of the metal, fused it, and that it ran into globules.

13. This first experiment was, in some measure, nothing more than a hint to philosophers concerning a property unknown, and till then even denied, in mercury; it has since been often repeated, and of late it has become as easy and simple an experiment as most of those that are made in chemistry. In the year 1772, Pallas caused mercury to congeal, at Krasnejark, by a natural cold of  $-55\frac{1}{2}$  deg. of Fahrenheit's scale; it was observed, that it then resembled soft tin; that it could be flattened; that it broke easily, and that its fragments, when brought into contact, were glued or soldered together, as happens in all other softened metals; however, it is evident, that he did not obtain its real conversion into a solid, or complete concretion, as the mercury was still soft and only in a state of semi-congelation. In the year 1775, Mr. Hutchius observed the same congelation at Albany-fort, and Mr. Bicker at Rotterdam, in 1776, at 56 deg. below 0. In the year 1783, the congelation of mercury was effected in England with a less degree of cold; and Mr. Cavendish has proved  $31\frac{1}{2}-0$  of Reaumur's thermometer to be the real degree at which it took place.

14. In



14. In the Polytechnic school, within a few days after its installation, on the 18 Nivose of the 3d year of the Republic, (Jan. 5, 1795), the experiment of the congelation of mercury was performed by refrigerating mixtures of ice and muriate of soda, of ice and nitric acid. The temperature of the atmosphere being 9-0, a thermometer with alcohol descended by the refrigeration of these mixtures, used alternately as baths, to 31-0. Mercury, in a state of considerable purity, inclosed in bulbs of thin glass, and immersed in this cold of 31-0, passed into the solid state. At the moment when the congelation took place, the person who held the tube of glass in his hand perceived a slight concussion, produced by a sudden retreat of the fixed metal; a species of phenomenon which is also perceived very sensibly when phosphorus becomes fixed. A manifest crystallization into very small octahedrons was observed in the mercury. Pelletier having placed this solidified mercury in the hollow of his hand, experienced a painful sensation, which he compared to a burn. The part of the skin which had remained for a certain time in contact with this substance, exhibited a white spot, which afterwards became red, and remained very visible during several days subsequent to the experiment. This mercury, being beat upon an anvil of steel, and with a hammer cooled to 17, was very much flattened, and showed a sufficiently marked ductility.

15. The

15. The chemists of the polytechnic school wished moreover to ascertain the proportion between the capacity of solid and that of liquid mercury, and how much caloric it absorbed in order to become liquefied: this they did, as far as was within their power, by mixing, in a hollow piece of charcoal, solid mercury at  $31-0$  with liquid mercury at  $8-0$ . The result of temperature which they obtained led them to conclude, if not with perfect accuracy, at least in a manner approximating to it, that solid mercury absorbed, in order to its fusion, a quantity of caloric, which, if transferred to the same proportion of liquid mercury, would raise its temperature by nearly 69 degrees, that is to say, would heat it to near  $38-0$  Reaumur; that it was consequently much less dilatable by a given porportion of caloric in its solid than in its liquid state.

16. This result, which is not yet rigorously exact, except as considered in a general point of view, coincides with a singular property which has been very frequently observed in mercury, namely, that at the moment of its congelation, the mercury suddenly contracts in a considerable degree, which is the cause of the shock or concussion that is felt in holding the vessels in which this congelation is effected. This phenomenon has even deceived several observers, who, in considering the conversion of mercury into a solid, have judged of the reduction of temperature at which it took place,

place, by adopting as a measure of this reduction, the point to which this metal had descended in the thermometer at the very moment of its congelation, a point, which, besides the product of the congelation, exhibits also the effect of its sudden shrinking or instantaneous contraction.

17. It has been concluded from the flattening which solidified mercury experiences from the percussion of the hammer, that this metal possesses a certain degree of ductility, and it is on this account that I have placed it together with zinc in the third division of the metals, which have the character of semi-ductility. But it is very evident, that this property is extremely limited, that it cannot even be ascertained without many difficulties, and that it is as yet far from having been sufficiently appreciated. The precaution has not even been used, except in the last mentioned experiment, which, however, could not be carried far enough, of employing, for the purpose of trying the malleability of mercury, instruments cooled to that lowness of temperature, which alone can retain it in its solid state: it has, therefore, been speedily liquefied, and almost at the first strokes applied to it with the hammer, especially in the first trials; for in those of the polytechnic school, the steel anvil and the hammer having been cooled to 17—0, the solid ball of mercury received several strokes without either cracking or being fused; and it was only in the state

cf

of a flattened ball that Citizen Pelletier placed, and held it for sometime in the hollow of his hand. We therefore do not know either the tenacity, the hardness, or the elasticity of mercury; we only know that it possesses these properties in a very inferior degree.

18. Formerly much stress was laid upon the dryness of mercury, and its property of not wetting other substances; and it is certain, that this liquid metal does not attach itself to any of the bodies, that are wetted by water, the oils, or other liquids. But as this property of wetting manifestly depends upon the superficial attraction, which these liquids exert upon the bodies, it is evident, that the reason why mercury does not wet them, or does not attach itself to their surface, is because it has little attraction for that surface: thus it really wets the substances with which it is able to unite, such as the metals which it dissolves, gold, silver, tin, lead, &c. and we cannot clear it from the surface of these, to which it adheres strongly, except by the action of fire, in which they are not fusible, or by chemical operations employed in order to destroy the real combination which it has formed with them.

19. As a metal always fused, always liquid at the temperature of our climates, mercury constantly affects the form of perfect globules when it is divided. When inclosed in a glass phial or tube, its surface is convex, which de-

agitating it with very dry bread-crumbs, bran, and other desiccating means of a like nature. It is on account of this easy process of distillation, that chemists have considered mercury as the most volatile of all metals.

21. In its reduction into vapour by means of fire, and its subsequent condensation, mercury undergoes no alteration, if the vessels used for this operation do not contain much air, if the apparatus be well closed, and if the mercurial vapour be speedily condensed by the contact of the cold water. The distillation is nothing more than a mere physical change of state and form, effected in the mercury by the operation of fire, but it suffers no chemical alteration. Boerhaave had the patience to distil mercury 510 successive times, without its suffering any alteration; he only imagined that he observed the metal had become more brilliant, ponderous and liquid than it was before. In fact, he obtained in this laborious experiment a small quantity of grey powder, which appeared to him to be nothing more than mercury in a state of extreme division, and which required only to be triturated in a mortar in order to restore it to the state of brilliant liquid mercury. We shall soon see that this was a small quantity of the black oxide of this metal.

22. The alchemists conceived the exposure of mercury to a high temperature to be a means of fixing it, or of depriving it of its fusibility and volatility. For this purpose, several have  
advised

advised to inclose it in thick, and very strong vessels, and in this manner to subject it to the action of a violent fire for a longer or shorter time; but the trials of this kind, that have been made have only proved that this metal is in the same predicament with all those that are very expansible and volatile, and that so far from being able to fix it, the effect of the fire is only to separate its molecules from each other, to that degree, that in a state of great expansion, it forcibly breaks to pieces all the obstacles that oppose this separation. Hellot has related to the Academy of Sciences, that a person who wished to fix mercury, introduced a certain quantity of it into a very well-soldered globe of iron, which he threw into the middle of a burning fire; but scarcely had it become red-hot, when the mercury burst its receptacle with a loud report, and flew out of sight. The same phenomenon occurred in the house of Geoffroy, the apothecary. An alchemist filled a ball of iron, which he inclosed in several other spheres, the last of which was secured by two very strong hoops of iron placed cross-wise, and threw the apparatus into a well-heated furnace in order to make it red-hot. After a certain period, the mercury burst its enclosures with a loud noise, and the fragments of iron were thrown out with such force, that they penetrated through walls and partitions like bomb-shells. The same experiment may be made without the same danger, by inclosing

closing mercury in small glass bottles, closed at their extremity by the heat of a lamp, and throwing these bottles into the midst of the coals in a furnace placed in the open air. These vessels burst with a report, and the mercury, having nothing to resist its expansion, flies into vapour.

23. Mercury is a very good conductor of electricity and of the animal property known by the name of Galvanism. Its electrical property is probably the cause of the phosphorescence, and the considerably bright light which it emits, when it is agitated in a vacuum. This phenomenon was first observed in the year 1675, by Picard, a French geometrician, and member of the Academy of Sciences at Paris. This philosopher, as he was carrying, during the night, in a dark place, a barometer that had been kept for several years in the observatory at Paris, observed that the mercury whilst it was shaken in the tube, threw out luminous sparks similar to those which are emitted by phosphorus when exposed to the air. This experiment was then repeated upon several other barometers, and only one was found, belonging to the celebrated astronomer Cassini, which exhibited the same phenomenon. Mention was made of this property in a Treatise on Thermometers, Barometers, and Hygrometers, published at Paris in 1686, and at Amsterdam in 1708. The journals of the time also speak of it; but twenty five years elapsed before its  
exami-

examination was resumed. The celebrated Bernouilli described in the year 1719, in a work professedly written, *de mercurio lucente in vacuo*, or the manner of constructing luminous barometers, and proposed a kind of clepsydra formed by this metal, flowing out of one tube, into another, and which during the night, should indicate the hour, by the progressive and proportional diminution of the phosphorescent column. S'Gravesande, Weidler, Haukefbee, Homberg, Leibnitz, occupying themselves with the same property, made more or less ingenious applications of it to luminous showers, shining streams, perpetual lamps, and compared this phosphorescence with that of several other substances. Natural philosophers, whilst they confirmed the existence of this property, soon discovered that it was not constant, that it varied, that it obtained only in hot and dry weather, and when the vacuum was perfect, and the mercury very pure, and that it even became gradually weaker in proportion to the diminution of all these conditions. It has been discovered that this phosphorescence is an electrical phenomenon, which takes place only in consequence of the friction of the mercury against the sides of the tube, and that the mercury does not thereby suffer any sensible alteration.

24. A very peculiar smell and taste are easily recognizable in mercury. To convince ourselves that it possesses this property, nothing more  
is



is necessary than to rub it for some time between the hands. The skin retains a considerable quantity of it, and it is sufficiently diffused upon this organ for the olfactory nerves to be sensibly affected by it. Also when we pass it over the tongue, a kind of acrid taste, of an austere and metallic nature, is perceived, which, though analogous to that of several other metallic substances, has nevertheless a very distinct peculiar character, which one may learn to distinguish by habit. It is to this taste that several physicians ascribe the property which mercury is well known to possess, of killing small insects and worms; and it is to the same also that several attribute the effects of this metal in some cutaneous affections, the cause of which they have at the same time imagined they had discovered and explained, by supposing them to be produced by microscopical insects, though their existence has never been accurately proved nor admitted by a great number of other persons of the profession.

### *C. Natural History.*

25. THERE are, as yet, only four well-known states, or four well ascertained ores of mercury in the interior of the earth: the first is native mercury, and the second, the alloyed or amalgamated mercury; the third is the red sulphuret of this metal, and the fourth the red muriate of mercury. In general, the ores of mercury do

do not exist in nature in so great quantity, nor in such large masses as those of many other metals. They are a great source of wealth to the countries in which they are found; Spain, the Palatinate, Friuli, and some provinces of America, are the countries most favoured by nature with respect to this production, which is useful in a great number of the arts.

26. Native mercury, which has been termed virgin mercury, is found in the form of liquid globules, which are very easily recognized by their brilliancy and liquidity. It is commonly found in tender and friable earths and stones, and frequently interposed between the fissures and the cavities of its own orbs, especially of its sulphuret. It is seldom perfectly pure, and frequently contains some other metal with which it is alloyed; but when it is sufficiently liquid, it is considered as pure or really native. At Ydria, and in Spain, and America, it is collected in the cavities and clefts of the rocks, into which it filtrates from all sides. It is found liquid in argil at Almaden, and in the beds of chalk in Sicily. It is also found in the ores of silver and lead, and even mixed with the arsenious acid, or white arsenic.

27. Mercury, alloyed with other metals, exists more abundantly in the earth than native mercury, as the latter is rarely perfectly pure, and free from combination with any other metal. It is sometimes in superficial layers, extended over the surface of the gangue, and some-

times in solid grains which adhere to and line its cavities. The proportions of these two component metals vary greatly: frequently the proportion of mercury is so large that the amalgam is of the consistence of a paste, or semi-liquid. Bergman also speaks of the native amalgam of gold and bismuth. Some mineralogists assert that the amalgam of silver is found crystallized.

28. The red sulphuret of mercury, known by the barbarous name of cinnabar, is an ore which varies in its tints, from the lively and brilliant red of vermillion, to a brown colour, similar to that of several of the oxides of iron; its weight is pretty considerable; Muschenbroeck has estimated it at 2,233; Mr. Kirwan computes it at 7,000. Sometimes it is in compact masses, sometimes lamellated, composing part of veins; sometimes it is in small crystals of an indefinite figure, which Mr. Kirwan asserts to be cubes, and others, triangular prisms or pyramids, of a transparent ruby red; it is also found in powder, of a bright red colour, or in the form of an efflorescence, which is termed native *vermillion*, or *flowers* of cinnabar. It has naturally no metallic lustre; however, this lustre is seen in the pieces recently broken, but it constantly disappears to give place to the beautiful red colour which characterizes it when the broken piece is scraped. Citizen Haüy found that pieces of a perfectly lamellated texture, divided themselves very neatly into layers, parallel

parallel to the faces of a regular hexahedral prism. According to the same mineralogist, the fracture of this ore is rugged in the direction of the bases of the prisms just mentioned. He says, moreover, that he has never been induced to apply the theory of crystals to this species. We also find the sulphuret of mercury mixed with stones or sand, which are then red and very ponderous.

29. The fourth species of ore of this metal is the muriate of mercury. It is also termed *corneous mercury*, or mercury mineralized by the muriatic acid. Mr. Woulfe, an English chemist, was the first who discovered this mineral, at Obermuschel, in Deux-Ponts; it is always mixed with a small quantity of sulphate of mercury. This native salt is brilliant, white, and lamellated; sometimes it is found of a yellow or blackish colour, mixed with sulphuret of mercury. The muriate of mercury exists in it in the super-oxygenated state.

30. To these four very distinct species several mineralogists have added some other ores of mercury, which have however not been generally acknowledged, or which manifestly belong to other metals. Citizen Sage has described a native oxide of mercury, which came from Ydria, in Friuli, of a brown-red colour, very mild; and of a granulated fracture mixed with some globules of liquid mercury. He assures us that this ore is reduced alone, and without any addition, into liquid mercury, by the  
action

action of fire. Mr. Kirwan considers it as a native carbonate of mercury; it contains  $0,9\frac{1}{2}$  of mercury. Baron Born also speaks of a native oxide of mercury, in his mineralogical catalogue of the cabinet of Mademoiselle de Raab. Cronstedt, in his Mineralogy, has mentioned an ore of mercury, in which this metal is combined with sulphur and copper; according to his description, it is of a blackish-grey colour, brittle, and very ponderous; its fracture is vitreous; it decrepitates in the fire; it is found at Muschel-Landsberg. Citizen Monnet, in his *Système de Mineralogie*, has mentioned an ore, brought in the year 1766 from Dauphiné, by Montigny, in which he says he has found mercury, sulphur, arsenic, cobalt, iron, and silver. But as this is only a grey and friable mixture, containing not more than  $\frac{1}{100}$  of mercury, and  $\frac{1}{100}$  of silver, it is evident that it ought not to be reckoned amongst the ores of mercury. Finally, Baron Born has also spoken of an alkaline sulphuret of mercury; but the modern mineralogists justly consider its existence as very doubtful. It is evident that none of these four last-mentioned ores ought to be added to those which I have indicated as constant, sufficiently distinct, and well marked, except the carbonate of mercury, or the native oxide, were its existence well ascertained; for that of Cronstedt is nothing but a cupreous pyrites or sulphuret of copper, containing mercury, probably

bly disseminated in it, but not combined with it.

*D. Assay and Metallurgy.*

81. BEFORE the time of Bergman, the assay of the ores of mercury, and especially of the native sulphuret of this metal, for this was almost the only one attended to, was an operation, either very imperfect, or very superficial. In order to examine an ore containing mercury, it was mixed, in the state of powder, with lime or alkali; and this mixture was thrown upon a hot brick, which was immediately covered with a bell-glass, in which the mercury was volatilized and condensed, attaching itself in small drops to its sides. When this assay, which often was a sufficient inducement for undertaking works upon a large scale, was not deemed satisfactory, on account of the price of this metal, and when it was wished to ascertain how much mercury this ore contained, or was able to yield, it was distilled with substances capable of retaining the sulphur and disengaging the mercury from it, such as lime, the alkalis, and iron. Water was put into the receiver, a piece of linen was attached to the beak of the retort of stone-ware which was used; and after the operation, the mercury obtained was weighed; and the diminution of the weight which remained was also determined.

82. Instead of these defective operations, Bergman proposed, in his Dissertation on Humid

mid Assaying, to substitute real analytical processes. Native mercury is so frequently alloyed with foreign metals, that it is useful to determine their proportion ; for this purpose he proposes to dissolve it completely in nitric acid. If it contains gold, this remains in the state of powder at the bottom of the solution ; if it contains bismuth, it is precipitated by water, which does not separate the oxide of mercury. Silver is discovered by precipitating the solution with muriate of soda ; the muriate of silver and that of mercury are deposited together, but the latter dissolves in the water much sooner than the former, and they are separated by means of this simple process. It might be done still better by means of the oxygenated muriatic acid, which would dissolve the muriate of mercury without affecting the muriate of silver. The docimastic processes are the same for the native amalgams.

33. The red sulphuret of mercury is more difficult to be treated with the acids, which do not attack it without great difficulty. However it is decomposed by boiling it slightly with eight times its weight of a mixture of three parts of nitric and one of muriatic acid ; the metallic part is dissolved, and the sulphur is left in the form of a yellowish powder. I propose to substitute the oxygenated muriatic acid instead of this mixed acid. Bergman had already proposed to treat this sulphuret with muriatic acid and the oxide of manganese;

but as the mixture of the latter renders the sulphur very difficult to be separated, I prefer the immediate action of the oxygenated muriatic acid. By this means we find that 100 parts of red sulphuret of mercury contain 0,80 of metal, and 0,20 of sulphur. The mercury, in this natural combination, is manifestly in the state of an oxide, and this compound would better deserve the name of sulphurated oxide of mercury than that of sulphuret of mercury.

34. As to the native muriate and sulphuret of mercury, Bergman directs us to treat them with the muriatic acid, which seizes upon the oxide of mercury combined with a portion of sulphuric acid, and thus reduces the whole mass to the state of muriate of mercury: the liquid which floats at the top is separated by means of the muriate of barites, which gives the weight of the sulphuric acid contained in the native salt, by means of the precipitated sulphate of barites, and consequently that of the muriate of mercury which was originally mixed with it.

35. To these docimastic processes I must add the methods of ascertaining the purity of mercury, and those of procuring it in a very pure state. Motives of gain frequently afford an inducement for adulterating this metal, which always bears a more or less high price in commerce. The additions of lead and bismuth, the amalgams of which, though solid by themselves, have the property of assuming a considerable



which we operated. I shall add, on this occasion, that since large quantities of mercury have become necessary in laboratories for experiments upon the gases, I have had frequent occasion to examine this metal, in order not to be deceived in the purchase, and that I have never found it to contain more than four or five hundredths of foreign matter; that I am convinced; that the mercury is frequently soiled, covered with powder, tarnished, imperfectly liquid, and even draws a tail, without its containing on that account any remarkable quantity of inferior metals, and that these properties almost always depended upon a commencement of oxidation, or even upon the humidity contracted by the mercury.

37. In order to avoid the danger of employing impure mercury for the important purposes to which this metal is appropriated, as well in medicine as in natural philosophy and chemistry, and in several of the arts, it has always been advised to extract it for one's own use from the sulphuret of mercury: this is what has been termed *mercury revived* or *resuscitated* from cinnabar, an expression which pretty well expresses the oxidized state of the mercury in its ore. This operation is usually performed in chemical and pharmaceutical laboratories, by distilling, in a retort of iron or stone-ware, a mixture of iron and sulphurated oxide of mercury either native or artificial; for, as we shall see hereafter, the artificial compound is much

more



more frequent in commerce: the iron is added in the proportion of one part to two of cinnabar, and well mixed, in the form of fine filings, with this mercurial compound, by exact trituration. The distillation is performed with the precautions already mentioned; a piece of linen that forms a tube, is attached to the beak of the retort, and immersed in the water with which the receiver is half filled. The iron, whose attraction for oxygen and for sulphur is much greater than that of mercury, disoxidates and de-sulphurates the metal, which rises in the form of vapour, and is condensed in the water; there remains in the retort a sulphuret of iron, in which this metal is a little oxidated. The mercury obtained in this manner, when dried and passed through a skin, is very pure and brilliant.

38. It is by processes analogous to that which has just been described, that mercury is extracted in the large way from its ores. That which is liquid and disseminated in globules amongst the stones, is easily collected by diluting them in water after they have been pounded; the metal is precipitated, and the water, as it runs off, carries with it the earthy particles. It is in this manner that the native and liquid mercury is extracted at Ydria in Friuli. As to cinnabar, or the natural sulphuret of mercury, it will immediately be apparent that it cannot be roasted, either in order to diminish its cohesion, or to separate the sulphur, even in part, for the sulphuret would be

dissipated by the action of the fire. As nature almost always presents it mixed either with a calcareous or ferruginous substance, both these gangues become a kind of intermediate agents, very fit for decomposing the sulphuret, absorbing its sulphur, disoxidating its metal, and consequently promoting its volatilization by the heat.

39. The processes used in the extraction of mercury, though always founded upon distillation, vary according to the places in which they are practised. Antoine Jussieu has described, in the Memoirs of the Academy of Sciences for the year 1719, the operations performed at Almaden in Spain, for the purpose of obtaining this metal. He first observes, that the mines of this country do not emit any exhalation deleterious to vegetables; that the environs and the soil above them are very fertile; that the working of them is attended with no danger to the labourers, and that it is only the convicts employed in their interior, who are attacked with dangerous maladies, on account of the mercury volatilized by the fires which they are obliged to keep burning. The ore of Almaden, according to this author, contains iron and a small quantity of carbonate of lime. It is introduced into a kind of reverberatory furnaces, and the fire is kindled in the ash-hole. This furnace has no aperture except eight holes at its posterior part; to each of these holes a row of aludels of earth is adapted,

the last of which terminates in a small building at a considerable distance from the furnace. Between the two extremities of this apparatus, the building and the furnace, a small platform is constructed, forming two inclined planes, which support the aludels; when any ill-luted joining of these suffers any of the mercury to escape, its globules are collected at the meeting of the inclined planes of this platform. The fire applied to the sulphuret of mercury effects its decomposition by means of the lime and iron, which absorb the sulphur and oxygen. The mercury reduced into the state of vapour, is partly stopped, passes into the aludels, and runs down in part by the gentle slopes which they have into the small building. When the operation is completed, and the whole of the apparatus cooled, all the aludels are carried into the chamber of this building, in order to empty them, and collect the mercury which they contain, in a cavity in the middle of the chamber, towards which, it sublimes from all sides. This mercury is afterwards transported in skins, and in barrels that contain several quintals, which go by the name of *bouillons* in commerce.

40. In the Memoirs of the same Academy for the year 1776, we find a description of the process employed in the Palatinate for the extraction of mercury, by Citizen Sage. They there use a gallery charged with forty-eight retorts of cast iron an inch thick, more than a metre in length,

length, and containing about twenty-nine Kilogrammes (sixty pounds) of materials. These retorts are steadily fixed upon the furnace which supports them. A mixture of three parts of the ore well sorted and pounded, and one part of flaked lime is introduced into them by means of an iron ladle; they are heated with pit-coal, applied at the two extremities of the furnace, the sides of which are perforated with several apertures, which establish currents of air, and cause the coal to burn. The mercury is separated and volatilized by the re-action of the lime upon the sulphur; it is collected in earthen receivers adapted to the retorts, and filled with water to about a third of their capacity. This operation occupies ten or eleven hours. It is evidently founded upon the same principles as the preceding one, and differs from it only in the form of the apparatus.

#### *E. Oxidability by the Air.*

41. Formerly, mercury was not thought to be capable of burning, and it was considered as unalterable. It was by carefully examining this property that modern chemistry made its first and most valuable discoveries, and to these the pneumatic doctrine owes its rise. Mercury is not only oxidable like all the metals, but it has also two modes of burning, or two species of combustion, like the greater part of metallic substances: the one is the slight and imperfect com-

combustion, which takes place at a low temperature; the other is the complete and strong combustion, which is effected only at a very high temperature. The first was for a long time considered to be merely a division of the mercury; it has been very well described in this point of view by Boerhaave. Without knowing the cause, he converted mercury by it into a black powder, which he termed *Ethiops per le*, and of which he knew both its reductibility by heat, and the diminution of its weight during its reduction. The other, which has been considered by the alchemists as a kind of fixation or precipitation of mercury, takes place only at its temperature of ebullition, and converts it into a red powder, which they termed *mercury precipitated per se*. Each of these must be considered in detail.

42. The slight oxidation of mercury takes place at a very low temperature, and always when this metal is agitated in contact with the air. Aristotle already seems to have known it, when he says in his fourth book (*meteorolog. comm.* chap. xviii.), that by mixing mercury for a long time with saliva, a remedy is formed, which is useful in some diseases of the skin. Whether we rub the mercury with the hand, or frequently agitate it in the air, or, as Boerhaave did, cause it to be incessantly shaken in a bottle attached to the axis of a mill-stone, or triturate it with any liquids, provided they be thick, viscid and especially if susceptible of attracting

ing the oxygen of the atmosphere; in all these cases, it is converted into black oxide, of an acrid and copperish taste, which is restored to the state of liquid mercury by the action of fire, and even of light, which contains about a twenty-sixth of its weight of oxygen, and which is a real black oxide of this metal. We cannot rub mercury upon a white substance, or between the fingers, without oxidating a portion of it, and in all the operations, of which Plenck has performed such a variety, wherein the metal is extinguished in liquid viscous mixtures, or in any solids, that is to say, in which it loses its form of globules, and assumes that of a black powder, with the aid of motion and division in contact with the air, it is equally oxidated. The surface of mercury, when exposed for a long time to the air, even though it be at rest, becomes at length covered with a dull-coloured pellicle, which is nothing else than this species of oxide. Bernouilli, has even observed that on letting a globule of mercury fall from a height of thirty, and even of fifteen centimetres, upon a very brilliant and pure mass of this metal, a spot was formed at the place upon which it had fallen; and though he has attributed it to the impurities which the globule absorbed in the air, it is evident that it is entirely owing to the commencement of oxidation which it undergoes. This conversion into black oxide is even produced by agitating mercury in aerated water.

water. The same oxidation is likewise the cause of the black powder which frequently forms at the top of old barometers, which contain a small quantity of air. Lastly, if we observe with attention all the circumstances in which mercury becomes oxidated, by whatever process it may be, we find that it always passes through this state of black oxide, before it arrives at a more complete state of oxidation. In a word, this state of black oxide is constantly the first term of the oxidation of this metal, and we may equally observe, that it returns to it immediately before it assumes the metallic form, in all the cases of disoxidation, of which I shall soon have occasion to speak.

43. The strong or complete oxidation of mercury is an operation which the alchemists have long since practised, as I have already observed, and for which they have contrived apparatuses more or less complicated, which at present are altogether laid aside. Boyle, who was ignorant of the theory, though he occupied himself so much with the effects of the air, contrived for this process a flat bottle, which he closed with a long cylindrical stopper, perforated with a very small aperture through the middle, and which has been termed *Boyle's hell*, from the notion that the metal was put to a real torture in it. Boerhaave, in his numerous distillations of this metal, observed that he every time obtained a certain quantity of red powder,  
very



very brilliant, very acrid, and very active, so as to produce, according to his expression, a great derangement in the animal economy. He also discovered that this red powder was reducible into mercury by the action of fire; that the metal, by changing its form in this manner, acquired also fixity; but he supposed the cause of this change, which he admitted only in the form, to proceed from the fire, which passed through the vessels. In treating of this subject he has contented himself with combating the pretensions of the alchemists, and asserting that the mercury, in this case, was converted neither into gold nor silver. The complete oxidation of mercury into the red oxide has long been a very tedious and embarrassing operation in chemical laboratories; it was formerly necessary to employ several entire months in order to obtain a slight portion of this oxide; at present we succeed much more easily by means of a very simple apparatus. As the volatility of mercury is the obstacle to its complete combustion, since it cannot take place unless it be raised to a temperature sufficient to make it boil, chemists have contrived to give it a sufficient contact with the air to enable it to absorb the oxygen requisite to its oxidation, without affording it an aperture sufficiently large to admit of its being diffused in the atmosphere. For this purpose we take flat-bottomed matrasses, into which we

in-

introduce of very pure mercury as much as will entirely cover the whole lower surface with a stratum two or three centimetres in depth. The neck of these vessels is then drawn at the lamp till it is reduced almost to a capillary tube, and its extremity is broken in order to open a slight communication with the air. The matrasses are placed in a sand-bath, in which they are immersed as far as the place to which the mercury rises; a sufficient heat is applied to make the mercury boil gently, and in this state it is constantly kept. The metal rises in vapours, but falls back again, except the small portion which adheres to the sides of the matrass. After some hours, the surface of the mercury assumes a manifestly black colour, in consequence of the commencement of oxidation which it undergoes; after it has been continually exposed to the fire for some days, red particles are observed on its surface, which gradually increase in quantity, and at length entirely cover it; the motion of ebullition keeps them separate, and impels them to the sides, where they accumulate, as they are formed without interruption. When the motion is not too violent, several particles of red oxide collect and form transparent crystals of a ruby colour, which appear to be octahedrons, or elongated quadrangular pyramids. Almost all the mercury introduced into the matrass may be converted into red oxide, by continuing the operation for several months in succession.

cession. It is procured in sufficient abundance by placing a great number of these small matraffes in a large sand-bath; the operation goes on much more rapidly and the crystals of the oxide are much more perfectly formed, and more brilliant, if we cause pure oxygen gas, extracted from the super-oxygenated muriate of pot-ash, to pass into the matraffes.

44. The red oxide of mercury obtained in this manner contains nearly a tenth part of its weight of oxygen, according to the researches of Lavoisier. It is not only very acrid, purgative, and emetic, as Boerhaave observed, but also caustic and corrosive; it is a medicine so violent in its effects, that it ought to be reckoned amongst the poisons. If we heat it in open vessels, it sublimes into a transparent vitriform substance, of the most beautiful ruby-red colour. When it is gently heated, and constantly agitated in the air, it becomes brown, and nearly of the colour of tobacco. When strongly heated in close vessels, in the pneumato-chemical apparatus, it yields pure oxygen gas, and is reduced. It was by this experiment that Dr. Priestley, made the celebrated and useful discovery of this gas, in the year 1774; and it is upon the investigation of this reduction, compared with the inverse experiment of the decomposition of the air, its alteration, and its partial absorption by the metals, which increase proportionably in weight, that Lavoisier has laid the first foundations of the

the pneumatic doctrine. This is therefore a very interesting oxide to chemists, as it has been the source of one of the most illustrious discoveries, and one of the most important truths which our age can boast. Whenever we carefully observe the phenomena of its reduction, performed with caution, we see it grow brown in proportion as it gives out its oxygen in the form of gas; and there frequently remain some particles of black oxide in the vessel which has been used for this operation: the mere contact of the light of the sun, continued for a long time, is sufficient to effect, or at least to commence this reduction; this contact causes it to pass again to the brown, the orange, and the yellow colour.

45. We have a new and strong proof, both of the difference of the two oxides, the black and the red, which are obtained by the immediate combustion of the mercury, and of the superior strength of attraction of the first portion of this principle over that of the second, in the relinquishing of this last portion, of that which causes the oxide to pass from the black to the red state; which this oxide, in the last-mentioned state, makes to running mercury when triturated together with it. I have found, that by this trituration, the running mercury soon loses its lustre, its metallic state; its fluidity is extinguished, according to the common expression, and by causing the red oxide to pass  
to

to the brown or blackish state, shows that it divides with it the portion of oxygen in question. Moreover we shall see, by several facts which shall be mentioned hereafter, that, in the oxide of this metal, the oxygen possesses but little solidity, having lost only a small portion of its solvent caloric; that it is on this account that its formation is so tardy, and that it is so readily decomposed, and so easily relinquishes its oxygen; that it adheres so slightly to it, that it abandons this principle to a great number of other combustible substances, and so easily and violently inflames several of these, especially some of the metals, as zinc, tin, &c.

*F. Union with Combustible Bodies.*

46. MERCURY contracts no union with azote, hydrogen and carbon: we know of no azoturet, hidruuret, or carburet of mercury; but the two last mentioned combustible substances act sensibly upon its red oxide. Hydrogen kept long in contact with this oxide in the cold, colours it by degrees, and causes it to pass into the state of black oxide. This experiment succeeds much more quickly by heat. If we cause hydrogen gas to pass through a tube containing red oxide of mercury, heated to the first point of ignition a detonation takes place; the mercury passes into the metallic state, some remains of black oxide

oxide are left in the tube, and the water that has been formed is disengaged. This detonation proves that the oxygen which saturates the mercury is not in a very solid state, and that it retains a large portion of its original solvent caloric, which separates in its union with the hydrogen.

47. Carbon does not reduce the oxide of mercury unless by the aid of heat. This operation, which affords carbonic acid gas and running mercury, is one of those which ought to be repeated with the greatest care in experiments performed for the purposes of demonstration, as it is one of those which prove most incontestibly, and at the same time, the existence of oxygen in the metallic oxides, the proportion and nature of the carbonic acid, and the respective quantities of this principle and of carbon, which enter into the composition of the gaseous acid produced. By means of a simple calculation, it may be performed in so exact a manner, that no carbon shall be left behind, and the whole mixture shall be converted into pure running mercury and carbonic acid gas.

48. Phosphorus does not unite with mercury without great difficulty, and only by particular management.

A. Pelletier having exposed upon a sand-bath, for a space of nearly three months, a small matrafs half full of water, at the bottom of which he had put equal parts of mercury and  
and

and phosphorus, which remained always fused by means of the temperature of the bath, and which he agitated from time to time, these two substances formed no union with each other, but remained separate. The lower part of the concrete phosphorus which rested upon the mercury, having become brilliant and of a silver colour by the adhesion of this metal to its surface, announced, however, the existence of an attraction between these two bodies, and induced Pelletier to attempt their combination by other processes.

B. Having put equal parts of phosphorus and mercury into a small retort, he distilled till a small quantity of phosphorus passed over, after which, he suffered the apparatus to cool. The retort being broken, exhibited the mercury and the phosphorus separate, and without any combination.

C. Equal parts of phosphorus and red oxide of mercury, (about eight grammes of each in all these experiments) being covered with a small quantity of water in a matrafs, were exposed to the heat of a sand-bath, and stirred from time to time; the oxide soon became blackish, and united with the phosphorus; the water contained phosphoric acid. Pelletier considers the black powder to be mercury in a state of division, and conceives this division to be necessary to the phosphoration: it is very possible that this metal might have become phosphorated in its state of black oxide.

D. The

D. The phosphuret of mercury thus formed, becomes soft in boiling water, and assumes consistence in the cold : when kept in very hot water, after having been inclosed in chamois leather, and slightly pressed, a small quantity of transparent phosphorus was separated. What remained in the skin was solid black mercurial phosphuret, which could be cut with a knife, containing in its interior part uncombined globules of mercury. When heated in a distilling apparatus, it is decomposed, and yields phosphorus and mercury in a separate state. Exposed to a dry atmosphere, it diffuses white vapours that have a phosphoric smell. There exists, therefore, no very intimate union between the mercury and phosphorus.

49. Mercury unites very readily with sulphur, both by simple trituration in the cold, and by the action of the fire. When we triturate this liquid metal with two parts of sulphur, we soon perceive the mercury to disappear, become extinguished, assume and give to the sulphur a black colour, on which account this preparation was formerly termed *Ethiops Mineral*.

The mere inspection of the experiment is sufficient to show that in this operation the mercury is converted into the state of black oxide, and that the same holds good in its combination with sulphur, as in that with phosphorus of which I have just treated ; namely, that it unites with it only in the state of black oxide. When the mercury has entirely



lost its form and metallic lustre; when it is entirely converted into an uniform and homogeneous black powder, which grows blacker and blacker by the contact of the air, the operation is completed; the black sulphuret of mercury is prepared. In order to prove that in this trituration something more than a simple mixture takes place, that the sulphur actually combines with and adheres to the mercury, Chemists have observed, that they cannot be separated except by chemical means, and with the aid of the attraction of several other bodies. Notwithstanding this commencement of combination, a strong magnifying glass enables us to distinguish oblong globules of mercury in the black sulphuret formed in the cold, and by simple trituration: it whitens gold when rubbed upon it; it diffuses a fetid smell, and yields a black pellicle when treated with the liquid alkalis; it contains more sulphur than the following, and the two substances which compose it are less adhering, less intimately combined with each other.

50. When we throw mercury in a state of very minute division, by pressing and causing it to fall in a shower, through chamois leather into an equal quantity of fused sulphur, and agitate the mixture, the black oxidation of the mercury, and its combination with the sulphur, which assumes the same colour, take place very speedily. We must stir the mixture without interruption, remove the mixture from the fire,

when the mercury has almost intirely disappeared, and continue to stir it after it has been taken off the fire, till by refrigeration and agitation, the whole is converted into small-clots these are pounded in a mortar into a fine powder, which is passed through a fine sieve, and preserved under the name of *black sulphuret by fire*, or *Ethiops mineral by fusion*. All chemists agree in asserting, that, in this sulphuret, the sulphur and the mercury are more intimately combined than in that which is made in the cold. Wallerius assumed, as its characteristics of distinction from the former, its not whitening gold, its containing less sulphur, its not presenting globules of mercury visible by the magnifying glass, but shining and radiated particles, like a sulphureous ore; its not forming pellicles, and its diffusing a much weaker smell when subjected to the action of alkaline leys. It is observed, moreover, in preparing it, that this combination made by the action of fire, is very susceptible of inflammation; and when this takes place, it is extinguished in order to preserve its state of black sulphuret; otherwise it would pass into the violet, and assume the character of the red sulphuret.

51. A black sulphuret of mercury is also formed by triturating the red oxide of mercury for some time with sulphur. We must be cautious not to heat this mixture too much when we wish to promote it by the action of fire; for it is susceptible of detonation, according to the

periments of Bayen, who has made all the oxides of mercury fulminate, indeed by a small quantity of sulphur, and by heating them strongly. The same combination into black sulphuret takes place also when we agitate mercury in water charged with sulphurated hydrogen gas, as I have discovered in analyzing the water of Montmorency; by treating the red oxide of mercury, or precipitating its acid solutions, by the same water, or by the alkaline hydro-sulphurets. It is therefore evident that, whether we take running mercury, or treat the most perfect oxides of mercury with sulphur in a state of division, this metal always passes into the state of black oxide, in order to combine with the sulphur. In the first case, it absorbs from the air about a twentieth part of its weight of oxygen, which it requires for its conversion into the state of black oxide; in the second case, it loses, on the contrary, all that it contains of this principle, exceeding one-twentieth part of its weight only, which it requires in order to unite with the sulphur: hence it is concluded that the *Ethiops mineral* of the ancient chemists is really the *sulphurated black oxide of mercury*.

52. The rapidity with which running mercury becomes oxidated, and absorbs the twentieth part of its weight of oxygen, at the moment when it is combined with sulphur, proves that in this combination its attraction for the principle of combustion is increased: it does not

not even remain in this first degree of oxidation, when the temperature of the sulphurated black oxide of mercury is raised. When we heat this compound in an open vessel, the sulphur which exists in it in a state of very minute division, and which is consequently very much disposed to burn, soon inflames and is converted into sulphureous acid vapour; the mercury at the same time experiences a higher degree of oxidation, and after having lost the greater part of its sulphur, so as to retain, to all appearance, not more than an eighth, or even a tenth of its weight, it passes into the state of a powder of a very deep violet colour, when the combustion of the more abundant portion of the sulphur contained in the sulphurated black oxide of mercury has ceased. If in this state of violet powder we heat the compound thus modified, in a matrafs, with a strong fire, it sublimes into a cake of a deep shining red colour, exhibiting crystals in the form of needles, which in the ancient nomenclature was termed *artificial cinnabar*, because it very much resembles the natural cinnabar, and which I term *the red sulphurated oxide of mercury*. The authors of chemical processes vary amongst themselves with respect to the mode of preparing this compound. That which succeeds the best and yields the finest product, has been described by Vogel. Seven parts of mercury, passed through leather, are mixed with one part of fused sulphur in an earthen vessel, and the mixture

mixture is well stirred till it is completely converted into black sulphurated oxide. This sulphuret is put into a phial, or rather a matrafs, which is placed in a crucible containing sand, and this is gradually heated till the fire acts upon it with sufficient force, and till the matter is perceived to be sublimed in the upper part of the glass vessel. It is then removed from the crucible, and after it has been broken, we find a red mass in the form of needles, the colour of which is the more brilliant and beautiful the stronger the operation of the fire has been, and the less sulphur the mercury retains. It is superfluous to rectify this red sulphurated oxide of mercury, and especially to repeat this tedious, difficult, and expensive operation, six or seven times in succession, as some chemists recommend; for when it has been well performed, the product is very beautiful and pure after the first.

53. Chemical authors differ greatly in their opinions respecting the proportions of the principles of the *artificial cinnabar*. Lemery believed it contained sulphur in the proportion of one part to two of mercury; Cartheuser in that of 1 to  $7\frac{1}{2}$ ; Mender of 1 to 30; Macquer of 1 to 7 or 8. Hence, some chemists have imagined that this compound might vary according to the relative quantities of sulphur and mercury employed in the preparation of the *Ethiops mineral*, with which it is fabricated. What is practised in this particular in  
the

the manufactories of Holland, proves that sulphur exists in the proportion of less than a tenth in this preparation, when it has the quality; which, on account of its fine colour, is in request in the arts. Tuckert, a Dutch apothecary, has described in Crell's Journal the process of fabrication employed in a laboratory at Amsterdam, in which a great quantity of it was prepared. This process has been published in the French Annals of Chemistry, Tom. IV. p. 25. The black sulphurated oxide of mercury is first prepared, by mixing 150 parts of sulphur with 1080 of mercury, exposing this mixture to a moderate fire, in a flat polished iron pan; it is then beat small and put into small earthen flasks, intended for pouring the matter, in separate portions, into the apparatus in which the red sulphurated oxide of mercury is prepared. This apparatus consists of three large earthen jars, previously covered on the outside with dried lute, and placed in furnaces so that the flame circulates freely round the jars. In the evening a turf fire is kindled under the vessels, so as to heat their bottoms to redness; when they are red, the contents of one flask is thrown into the first jar, that of the second into the second, that of another into the third, and in this manner they continue successively to pour into each of them to the amount of two or three flasks at a time, according to the violence and rapidity of the inflammation; for the black sulphurated oxide of mercury

mercury at this red heat, kindles instantaneously, and the flame frequently rises to the height of one, and even two metres above the jars. When this inflammation has subsided a little, each jar is closed with a plate of cast iron, which fits it exactly. The operation of pouring the matter into the jars, occupies thirty-four hours, and each of these vessels contains 410 parts of matter; namely, 360 of mercury and 50 of sulphur. The heat is kept up under the vessels till the whole of the matter is sublimed, which requires the fire to be kept burning for thirty-six hours: the fire is moderated according to the height of the flame which appears when the cover is taken off; the operation proceeds as it ought, when this flame, though sufficiently brisk, does not rise to more than 9 or 12 centimetres height above the mouth of the jars: during this time, the matter is stirred every half hour with an iron rake. When the operation is completed and the jars have cooled, they are removed, together with the circles which support them; they are then broken in pieces, and in each are found 400 parts of red fulphurated oxide, ten parts being lost in each jar. The workmen assured Mr. Tuckert, that they had never met with any accident in performing this operation, during thirteen years that they had been employed in the establishment.

54. The circumstances of this process seem to me to prove also that the mercury is oxidated  
in

in the artificial cinnabar; and this opinion is besides supported by several other facts belonging to the preparation of this compound. Whenever we agitate running mercury in a solution of hydrogenated ammoniacal sulphuret, or of hidro-sulphuret of ammonia, or precipitate a solution of this metal by means of either of these compounds, we have at first a black sulphurated oxide of mercury; but by being left to stand for some hours in the liquid, this substance soon assumes a brilliant and magnificent red colour. The same phenomenon takes place with the sulphurets with bases of fixed alkalis or earth, but less speedily than with that which has ammonia for its basis, and the red colour is never equally beautiful, but it remains of a pale brown, or dull brick colour. It has already been proved, that in these operations, the mercury does not pass from its metallic into the black state, otherwise than by a commencement of oxidation. It is evident, that in passing from the black to the red, it becomes more oxidated, and that it is the oxygen which imparts to it the red colour by which it is distinguished; I have therefore thought I ought to term it the *red sulphurated oxide of mercury*.

55. The characteristic properties of this compound are of themselves sufficient to prove the oxidated state of the mercury which it contains. It is unalterable by the air; when heated in a close vessel, it sublimes without decomposition;



tion; when gently and gradually heated in an open vessel, the sulphur is volatilized, and the reduced mercury is completely dissipated; this is what takes place when it is employed in fumigations; it does not colour nor whiten gold; the acids do not attack it, though they have in general the property of dissolving the sulphurated metals. If some of them dissolve it in course of time, they do it without motion or effervescence, as they would dissolve an oxide of mercury. Lime, the alkaline earths in general, and the alkalis decompose it; they absorb from it the sulphur, and separate the mercury, which is reduced and volatilized, losing at the same time its oxygen by the heat which is employed for this distillation. Cobalt, bismuth, antimony, tin, iron and copper possess the property of separating the mercury from it by absorbing the sulphur. We find also that these metals are the same as deprive mercury of oxygen, and consequently reduce its oxide. If even it has been found that silver disengages the mercury from cinabar, and it has thence been inferred that its attraction for sulphur is superior to that of mercury; but it was not perceived that this proceeded only from a triple attraction exerted in this operation; namely, that of the caloric for the oxygen and the mercury, and that of the silver for the sulphur, with which it unites in proportion as the disoxidated mercury

mercury abandons it, and is no longer capable of remaining in combination with it.

56. In the preparation of the oxide of mercury by the humid way, which is effected by agitating the running metal, especially in the hydrogenated sulphuret of ammonia, it is possible that a portion of the sulphurated hydrogen may unite with the oxide of the metal which is formed, and that the cinnabar obtained by this process may differ from that which is prepared in the ordinary way. This subject well deserves a particular investigation. It can not be doubted, also, that when, in precipitating a solution of mercury in an acid, the oxide returns to the black state, a large portion of the oxygen which it loses is transferred to the sulphurated hydrogen; and that it is on this account that the water, which holds this sulphurated hydrogen in solution, like the sulphurets hydrogenated with the liquid alkaline sulphurets, which afford a like result with the mercurial salts, lose their fetid smell at the moment when they form black sulphurated oxide of mercury.

57. Mercury unites with many metallic substances; it dissolves them, softens them, and forms with them combinations which are termed amalgams: these possess greater solidity, in proportion as the quantity of foreign metals which they contain is greater than that of the mercury. Though the action of fire in general decomposes them, and separates the mercury  
which

charges itself equally with air, and places itself in the equilibrium of combination, whenever it is in contact with it.

64. Boiling water produces no more alteration in mercury than cold water. Lemery had already proved, at the end of the last century, that this metal lost nothing of its weight by ebullition in this liquid. Boerhaave, who repeated this experiment with indefatigable patience, and boiled a great number of times considerable quantities of water upon four grammes of mercury, was likewise convinced, that this metal had not lost any thing. However, good medical observers have well ascertained, that this water, in which a linen bag, filled with mercury has been suspended during its ebullition, has a very decided anthelmintic or vermifuge property, and it is a very common practice to prescribe this decoction to children, who frequently void worms after having taken it. Some physicians ascribe still much greater powers to water which has been several times distilled upon mercury; pretending that this water is sensibly antisyphilitic. Wallerius, in order to explain its effects, supposed that the mercury re-acquired in water, with which it became penetrated, a weight of the matter equal to what it lost by its ebullition, and that it was on this account that its diminution could not be ascertained. Grashuys, who, in his letter to Dr. Maty, in 1754, speaks of the anti-venereal virtue communicated to water by mercury,

mercury, advances even that this metal, after being employed for this operation, loses its former efficacy, and possesses afterwards no longer the property of killing insects. However, it must be admitted, that it would require experiments still more decisive than those which have hitherto been performed, in order to afford satisfactory evidence of the truth of such assertions.

65. What has been said in No. 62, concerning the decomposition of the red oxide of mercury by means of a great number of metals, proves that mercury is one of those which have the least attraction and adhesion to oxygen: there are accordingly but very few, and those only amongst the least combustible, which are to be examined hereafter, from which it is able to take away oxygen. Nevertheless, by triturating running mercury with certain metallic oxides that are very much charged with this principle, and in which the last portion which is combined with them, has little adhesion in comparison with the first, which they retain with great force, it is found to be quickly extinguished and converted into black oxide. This does not take place except with those among these oxides especially, which are too much oxidated to be still soluble in the acids, and in fact, we shall see hereafter, that the same metals, on the other hand, precipitate mercury from its acid solutions, in the metallic form, and take its place in those solutions.

*H. Action upon the Acids.*

66. It was by the combination of mercury with the different acids, that chemists discovered the most singular properties, and at the same time the most important uses of this metal. There is no acid which does not act either directly or indirectly upon mercury, or which does not combine with its oxide, and form a saline compound more or less interesting in its properties. The phenomena exhibited by these different compounds, whether during their formation, or after they have been formed, deserve to be studied with attention, because they constitute one of the most remarkable branches of chemistry. I shall, therefore, describe them with all the proper details, because the treatises of chemistry do not yet contain these details, and because the investigations which I made relative to this subject, in the year 1791, seem to me to be capable of throwing a new light upon its combinations.

67. Previous to the year 1777, chemists had determined only in a very inaccurate manner, the nature of the reciprocal action of the sulphuric acid and mercury. All that they had done till then, could afford only uncertain and vague notions, on account of the state of the science. At this period, Lavoisier made use of that action in order to determine the nature of the sulphuric acid; he showed that mercury,  
assist-

assisted by the action of heat, deprived this acid of a portion of its oxygen, disengaged sulphureous gas from it, became itself oxidated, and combined with the undecomposed portion of the acid; that by strongly heating the sulphate of mercury, sulphureous acid gas and oxygen gas were obtained, and that the greater part of the mercury returned to the metallic state: but as his intention was only to occupy himself with the analysis of the sulphuric acid, he has not described all the phenomena of this combination. Thirteen years after him, in 1790 and 1791, I undertook a much more comprehensive investigation of the subject; I examined with great attention all that passed in the reaction of the sulphuric acid and of mercury: amongst a great number of new facts which this investigation presented to me, I perceived several circumstances, which had been glanced at, or indicated, but not explained, by Kunckel, Rouelle the elder, Monnet, &c. I have been enabled to distinguish with precision several states of the union of the oxide of mercury with the sulphuric acid, which had been mistaken or confounded. I proceed to give the result of my inquiries into this subject.

68. The principal cause of the numerous varieties presented by the solutions of mercury in the sulphuric acid, depends less upon the proportion of the acid and of the metal, than upon the quantity of oxygen which the latter absorbs from the acid, according to the tem-

perature in which their reciprocal action exerts itself. In fact, the proportion of one part of running mercury to a part and a half of concentrated fulphuric acid, which are generally taken for this operation, and which are known not to act upon each other in the cold, gives rise to a great variety of compounds, according to the temperature in which they are treated, and the length of time during which heat is applied to them. This mixture heated to ebullition in a glass retort, the curved beak of which is plunged under a bell-glass filled with mercury, in the hidrargyro-pneumatic apparatus, yields sulphureous acid gas. In this operation, the attraction of the mercury for the oxygen is increased in proportion to the increase of temperature; for at the ordinary temperature, it is much weaker than that of this principle for the sulphureous acid, and not for the sulphur as Lavoisier imagined: in fact, it has been shown in another place, that the portion of oxygen which adheres to the sulphureous acid, brought to the sulphuric state, adheres to it less strongly than that which is united with the sulphur in the sulphureous acid. Mercury decomposes the sulphuric acid, deprives it of oxygen, and causes it to pass into the state of sulphureous acid. If we stop the operation when the mercury is converted into a white mass, but not dried, and when a portion of liquid still remains upon the surface of this mass, it contains uncombined sulphuric acid; it is acrid  
and

and corrosive; it reddens the blue vegetable colours; it does not become yellow by the contact of the air; neither cold nor hot water convert it into that yellow powder, which formerly was called *Turpeth mineral*, on account of its colour, and of which I shall speak hereafter, provided we use the precaution of first separating the acid by a slight lixiviation with cold water; for otherwise it would become yellow by the effect of the heat produced in the re-action of the water and the acid. I term this whole mass, which results from the action and the doses of sulphuric acid and mercury that have been indicated, the acid fulphate of mercury. It cannot form turpeth unless when it is heated and desiccated.

69. This acid fulphate of mercury may contain very various proportions of sulphuric acid, accordingly as the original proportion has been varied; for it is very evident, that we should obtain a mass equally acid, by employing more of this substance than the proportion above indicated, and accordingly as we might have likewise disengaged a greater or less quantity by the action of the fire: it is in general the more soluble in water the more acid it contains, as has already been observed by all the chemists who have spoken of this combination before me. But a circumstance which has escaped their observation, is, that if we lixiviate the acid fulphate of mercury with much less water than would be requisite in order to dissolve it



much more sulphate of mercury, and raises the salt to a state of much greater acidity. The portion of this salt that remains after this first lixiviation, now requires five hundred parts of water for its solution, because it has become a real neutral salt. Thus the water employed in small quantity takes up the whole excess of acid, and such a portion of salt, that this contains a higher excess of acid than was contained in the whole original mass.

71. In order to prepare the turpeth mineral, the sulphuric mercurial mass that has been treated of in No. 68 was condensed by a longer continued action of the fire. A larger quantity of sulphuric acid was decomposed; the mercury was more oxidated, and hot water having been afterwards poured upon the mass, it afforded the yellow powder known by the name of *Turpeth*. In this preparation the oxide was obtained in different states, of a great variety of colours, from the pale citron-yellow almost to the orange-red, without its being possible formerly to account for these differences, and consequently to conduct the operation in such a manner as to obtain this compound always of the same colour and the same nature. Of the great number of experiments which I have made upon this compound, I shall here enumerate such as may throw a light upon its properties and composition.

a. If we do not evaporate the mixture of sulphuric acid and mercury rather briskly and  
by

by means of an elevated steady temperature, if there remain any very perceptible excess of acid not decomposed, or not volatilized, the mass dissolves in the water intirely, without assuming the yellow colour, and we obtain only a very small quantity of turpeth, by boiling the water for a long time with this mass; whilst, on the other hand, when the sulphuric mercurial mass is heated for a long time, it spontaneously assumes somewhat of a yellow tinge, and suddenly acquires a beautiful yellow colour, by the contact of the water.

b. Cold water poured upon the last-mentioned mass, gives it a beautiful greenish-yellow colour. Boiling water gives it a pure yellow colour, without any mixture of green; alcohol also renders it yellow, but in a less degree than cold water.

c. Several chemists have considered turpeth mineral as a simple yellow oxide of mercury, containing no sulphuric acid. Rouelle thought that it contained sulphuric acid; and my experiments confirm this opinion. By treating the best lixiviated turpeth with the muriatic acid, the muriate of barites precipitates sulphate of this base from the solution. For this reason I term the turpeth mineral *sulphate with excess of oxide of mercury*, or *yellow sulphate of mercury*.

d. In order to ascertain the nature of the change which takes place in the neutral sulphate of mercury, whilst it passes, by means of heat, into the state of yellow sulphate or turpeth,

peth, I strongly heated the former in a retort of porcelain: first, water was disengaged, afterwards sulphureous acid gas, then oxygen gas, and at the end of the operation, the mercury passed into the metallic and liquid form. At the moment when the sulphuric acid is disengaged, the salt, heated to redness, becomes fused and assumes a brilliant purple colour. By stopping the operation before oxygen gas is disengaged, and after the sulphureous acid has been disengaged, the salt is converted into yellow sulphate.

e. The properties which distinguish this salt with excess of oxide of mercury from the neutral and from the acid sulphate, all tend to prove that the mercury is oxidated in it much more abundantly and sensibly. In fact, this yellow sulphate is decomposed and dissolved by the nitric acid, which does not act upon the neutral sulphate of mercury; it is equally dissolved by hot muriatic acid, which converts it into super-oxygenated muriate of mercury, or *corrosive sublimate*, whilst this acid causes the neutral sulphate to pass into the state of simple muriate of mercury, or *calomel*.

f. The sulphuric mercurial mass, heated to the degree at which it yields yellow sulphate, scarcely receives the slightest tinge of yellow from water which has been boiled a long time before its being employed for this purpose.

g. This sulphate is heavier than the white mercurial mass from which it proceeds, when

we

we add the weight of the turpeth to that of the portion of salt dissolved by the water at the moment of its preparation.

*h.* The yellow fulphate, though it has hitherto been considered as insoluble, actually dissolves in more than two thousand parts of water at ten degrees, and in six thousand parts of boiling water: the solution is white.

*i.* Triturated with running mercury, it quickly extinguishes it, assuming at first a deep green colour, and soon passing together with this into the state of black oxide: when it is boiled with water and a small quantity of mercury, the same conversion into black oxide takes place, only more slowly than by trituration.

*k.* All these facts prove, that the yellow fulphate differs from the neutral and acid fulphates of mercury, by its containing more metal, more oxygen, and much less acid; and by the circumstances that in all cases in which it is formed at the expense of the two others, there is always oxygen added to the oxide, and sulphuric acid taken away from it, whether it be disengaged or decomposed.

*l.* One hundred parts of yellow fulphate of mercury gave me ten of sulphuric acid; seventy-six of mercury, eleven of oxygen, and three of water.

*m.* With the aid of heat, it is soluble in sulphuric acid a little diluted. Cold water precipitates from this saturated solution a white, and boiling water, a yellow oxide; when it contains

contains an excess of acid, it is not precipitated by water. We may re-dissolve the white precipitate in the fulphuric acid, and prevent the solution from being precipitated by an excess of acid.

72. Thus all the facts that have been announced, relative to the combination of the fulphuric acid with mercury, enable us to distinguish three sulphates of mercury, viz.

*a.* The neutral sulphate of mercury, crystallizable, soluble in five hundred parts of cold water, forming a grey precipitate by the action of the alkalis, not decomposable by the nitric acid, forming calomel with the muriatic acid.

*b.* The acid sulphate of mercury, more soluble than the preceding; forming an orange-coloured precipitate by the alkalis; from which the excess of acid, and a portion of the salt itself, is taken up by a fourth part of the quantity of water that would be requisite for its complete solution, leaving neutral sulphate of mercury after the solution, indecomposable by the nitric acid.

*c.* The sulphate of mercury with excess of oxide: it is yellow, soluble in two hundred parts of water; forms a grey precipitate by the alkalis; it is decomposable by the nitric acid; it forms super-oxygenated muriate of mercury with the muriatic acid.

73. Among the differences that distinguish these three sulphates of mercury, that of their precipitation by the alkaline substances ought particularly

particularly to be attended to. It is not easy to determine why the neutral fulphate, which is white, is precipitated into a deep grey by the fixed alkalis ; but it is evident, that if the acid fulphate is precipitated in the orange colour by the alkalis, this depends upon its suddenly absorbing oxygen from the atmosphere, by the aid of the heat which is developed in the mixture. As to ammonia, the action of which upon these salts has engaged my attention the longest, I have found that it precipitated the fulphates of mercury into a grey, more or less verging towards the black, and that it constantly caused their oxides, in whatever state they might be, to approach to the metallic state, by diminishing the proportion of oxygen which they contained. I have found, moreover, that this oxide, precipitated from the fulphates of mercury by ammonia, was less abundant than that which was separated by the earths and the fixed alkalis ; and this difference of quantity, which evidently exceeded the simple diminution that could proceed from their dis-oxidation, having shown me that the ammonia did not separate all the oxide of the fulphates of mercury, I discovered, by researches which this fact induced me to make, that a triple salt, or an ammoniaco-mercurial fulphate was formed : the principal properties of which I shall here announce, because the same formation of triple ammoniaco-metallic salts exists in many other solutions of metals, and must, in  
course

course of time, lead chemists to new and still more important discoveries.

74. When we pour ammonia into a solution of the neutral sulphate of mercury, a very abundant grey precipitate is formed, which, when exposed to the sun, is partly reduced into running mercury and partly remains in the state of grey powder. The latter is ammoniaco-mercurial sulphate; it is soluble in ammonia; it is not deposited with the first precipitate except when we do not employ an excess of ammonia in which it can be dissolved. When we employ a large quantity of the latter, we have only a small portion of an entirely black precipitate, totally reducible into running mercury by the action of the rays of the sun; in this case the liquor holds the triple salt or ammoniaco-mercurial sulphate in solution. In this operation, the ammonia decomposes only a portion of the neutral sulphate of mercury, the oxide of which it reduces. The ammoniacal sulphate that is formed, unites with the other undecomposed portion of the sulphate of mercury, and forms a triple salt of little solubility, but which is soluble in an excess of ammonia. The same decomposition takes place, attended with another phenomenon, upon this sulphate of mercury in its solid state. When we pour ammonia upon this salt, a brisk effervescence ensues, and a remarkable crackling noise is heard; a disengagement takes place of azotic gas, produced from the decomposition of the ammonia by the separated part of the

oxide of mercury; this occupies the bottom of the vessel in the form of a black powder, and the liquid that swims at top holds ammoniaco-mercurial sulphate in solution.

75. When the liquor which holds this salt in solution, after it has been formed by either of the processes that have been indicated, is evaporated, either with the assistance of heat, or by exposure to the air, it deposits at the end of some hours, brilliant crystals, of a polygonal form, and hard, the smallest of which, collected together, form a white and *chatoyant* pellicle upon the surface. This crystallization is owing to the evaporation of the ammonia which held the salt in solution. If, instead of waiting for this regular deposition, we suddenly add a large quantity of water to the solution, it becomes white and milky; a white powder is precipitated, which is nothing else than the same salt, but without any regular form, because it is separated suddenly: this proceeds from the circumstance, that the water which is added, divides the liquid, renders it lighter, and seizes upon the ammonia; there remains in the fluid sulphate of ammonia, which may be obtained in the form of crystals by evaporation. More of the latter is therefore formed than is requisite to cause the sulphate of mercury to pass into the state of ammoniaco-mercurial trifule as in fact is proved by the analysis of this, which contains more oxide of mercury than the metallic sulphate alone contained.

76. The



76. The ammoniaco-mercurial sulphate has a pungent and austere taste; when exposed to the action of heat, it decrepitates, and yields ammonia, azotic gas, a little running mercury, and a small quantity of fulphite of ammonia: there remains in the retort some yellow sulphate of mercury; it has little solubility in water; the alkalis and lime precipitate it into a white powder, which is still a triple salt with an excess of its base, or deprived of a large quantity of its acid. This precipitates when exposed to the sun, then blackens, and is reduced into running mercury, by the mutual decomposition of the mercurial oxide and ammonia. This ammoniaco-mercurial sulphate is soluble in ammonia, of which it retains a portion when it crystallizes by the evaporation of this volatile alkali. An hundred parts contain eighteen of sulphuric acid, thirty-three of ammonia, thirty-nine of mercury, and ten of water. This analysis proves, that this triple salt contains a very large proportion of the two bases compared with that of the sulphuric acid; and that in this combination, the attractions differ greatly, between the three substances which form it, from that which subsists between any two of them in particular.

77. All that we have just been considering relates to the decomposition of the neutral sulphate of mercury by ammonia. Other phenomena take place in the decomposition of the acid sulphate and the yellow sulphate, or the  
fulphate

fulphate with excess of oxide, by the same alkali; but these differences are easy to be determined from what has already been laid down. Ammonia poured into a solution of the acid fulphate of mercury, forms no precipitate in it, because the alkali, uniting with the excess of acid, is transferred, in the form of ammoniacal fulphate, to the fulphate of mercury with which it combines into a triple salt; it then perfectly resembles that of the liquor which floats above the black precipitate formed by ammonia in the solution of the neutral fulphate of mercury. The action of the same alkali upon the yellow fulphate is altogether the reverse of that which it exerts upon the acid fulphate: here the excess of oxide causes a much greater quantity of black oxide to be formed; instead of a triple salt, in consequence of the action of the ammonia upon this oxide; there is very little of the triple salt, or ammoniaco-mercurial salt formed.

78. In order to confirm all these new results respecting the formation of this triple salt, as to its nature, and especially respecting the difference of the saturation of the sulphuric acid by these two bases, which are united with it at the same time, I made a mixture of concentrated solutions of perfectly neutral fulphate of mercury, and equally neutral fulphate of ammonia; a white powder was immediately deposited, which I recognised to be a triple combination, and the liquor that swam at top contained a small quantity of un-

Vol. V.

G g

combined

combined sulphuric acid. This last-mentioned fact has particularly proved, that the oxide of mercury and the ammonia, in their reciprocal and simultaneous union with the sulphuric acid, require less of this acid, than the sum of these two bases would have required separately, in order to be each particularly saturated with it. I have also confirmed the cause of the portion of oxide of mercury precipitated in the black state, and reduced by the action of ammonia, by particularly examining that of this alkali upon the oxide of mercury formed by means of fire. I shall speak again of this action, in one of the subsequent Numbers.

79. No action takes place between running mercury, and the sulphureous acid; and this must necessarily be the case, because mercury decomposes the sulphuric acid only so far as to reduce it to the state of sulphureous acid; but a very strong action is exerted between the oxide of mercury, and the last-mentioned acid. If we place the red oxide of mercury and sulphureous acid in contact with each other, the oxide immediately becomes as white as milk, caloric is disengaged, and the odour of the sulphureous acid is instantaneously destroyed. When we employ only a small quantity of this acid, sulphite of mercury is formed; but if we employ a large quantity, the oxide of mercury is completely reduced to the metallic state, and sulphuric acid is found in the liquor. The last mentioned phenomenon is much accelerated

celerated by the contact of the rays of the sun. By this means, consequently, we can never obtain any thing else than sulphate of mercury. From the circumstances that in this experiment the red oxide of mercury is first converted into the white, and afterwards completely reduced by the sulphureous acid, we must not conclude that it contradicts the decomposition of the sulphuric acid by mercury; for there is no similarity between these two phenomena: the first takes place only in the cold, and the second is effected only with the aid of heat. The same experiment proves also that the white oxide of mercury contains less oxygen than the red.

80. The nitric acid is easily and rapidly decomposed by mercury; this action is much stronger than that which it exerts upon the sulphuric acid. It takes place in the cold, and as soon as these two substances are placed in contact with each other; it does not commence spontaneously, if the acid be too much concentrated, or too much diluted with water; it is accompanied with a disengagement of nitrous gas; it is one of the means of procuring this gas, and it is the experiment with which Lavoisier commenced his analysis of the nitric acid. The aqua-fortis of commerce acts upon mercury, without however diffusing much red vapour. When the operation is performed in a very long conical vessel, and when the acid covers the mercury to a considerable

height, a phenomenon is often observed which has imposed upon chemists. At the commencement of the operation, the acid assumes a bluish-red colour towards the bottom; this coloration is evidently owing to the nitrous oxide which separates itself from the inferior portion of the decomposed acid; and in fact, this oxide is not then disengaged in the form of gas, and the colour of the solution is augmented as long as there are no bubbles that rise to the surface of the liquor. Small bubbles are seen to arise from above the mercury, and disappear in the lower part of this liquid; when the more violent action develops more heat, the nitrous gas escapes, and the liquid loses the colour which it had assumed. This phenomenon proves that mercury has more attraction for oxygen than the oxide of azote has. In proportion as it burns, the oxidated metal is dissolved in the portion of acid, that is not decomposed, for much more acid is generally employed for this solution, than is required in order simply to oxidate the metal; and we may divide the whole, in idea, into two parts, relatively to the different action which each of them exerts upon the mercury, namely, the oxidating part, and the solvent part. The solution ceases when the proportion of the mercurial oxide, that has been formed, and that of the nitric acid necessary for its solution are in equilibrio. This acid may thus  
dissolve

dissolve a quantity of mercury equal to its own weight.

81. The nitric solution of mercury, made in the cold, is white and colourless; it is very ponderous, and so extremely caustic, that it is used in surgery, by the improper name of *mercurial water*, for corroding and destroying fungous flesh. It makes brown and almost black spots upon the skin, which do not disappear till the cuticle separates or peels off. It imparts the same colour to all vegetable and animal substances, and the tinge is indelible. It affords, either spontaneously or by evaporation, crystals of form very much varied according to the state of the liquor, and the circumstances that accompany the crystallization. I have seen them in four different forms, by spontaneous evaporation. I obtained transparent regular crystals, with fourteen facets, formed by the union of two tetrahedral pyramids, truncated as it were, very near to their bases, and with four angles resulting from the junction of the pyramids. The same solution, evaporated and afterwards left to cool, deposits, at the end of twenty-four hours, a kind of acute prisms, striated obliquely across, and formed by the successive opposition of small lamellæ, lying one upon the other in the manner of tiles. These lamellæ, when examined with care, appear to be the same masses with fourteen facets as the crystals above mentioned, but smaller and more regular than those.

those. A nitric solution, effected by the aid of a gentle heat, affords, when it is cooled, very long and sharp flat needles, striated lengthways; these are the crystals most frequently obtained: they have been described by most of the writers on chemistry, especially by Macquer and Rouelle. Finally, there is a fourth form, which is very irregular; namely, that of a white mass, frequently filled with long, silky, flexible, minute needles; but this belongs to another solution, or another modification of the nitrate of mercury, the properties of which it is necessary that we should consider.

82. Though some chemists have indicated the state of this second nitric solution before Bergman, it is to him that we are indebted for our first accurate knowledge of this remarkable modification of the mercurial nitrate. This illustrious chemist has observed, in his Dissertation on the Analysis of waters, that the nitric solutions of mercury differ from each other, according to the manner in which they have been prepared. That which is made in the cold, of which I have already treated, and which was not attended with any extrication of red vapours, is not decomposable by distilled water; but if the solution has been effected with the aid of heat, if a large quantity of nitrous gas has been disengaged in the operation, it will be precipitated by water, and it will no longer be capable of being used as a sure re-agent. I shall not enter here into a  
discussion

discussion of the erroneous theory which Bergman adopted in order to explain this difference; but I shall lay down that which I have been led to adopt, by my experiments upon this subject. This phenomenon proceeds from the same cause in the nitric solution as in the sulphuric. This kind of solution, with excess of mercury, is precipitated by distilled water, because this alters the density of the liquor, and diminishes the adhesion of the oxide of mercury with the nitric acid: accordingly, the precipitate is nitrate, with a great excess of mercury, very highly oxidated; and very yellow, if we pour the solution into hot water; or white, if we pour it into cold water. We may give the yellow colour of turpeth to the latter by washing it in boiling water at the very moment of its precipitation. The solution effected in the cold, on the contrary, containing only nitrate without excess of mercury, as it is only with the aid of heat that it can charge itself with a redundancy of oxide, distilled water cannot produce any precipitation in it. This proposition is proved by the circumstance, that we may render at pleasure the same mercurial solution decomposable or not decomposable by water, by adding to it either oxide of mercury or acid, and cause it to pass several times successively from one to the other of these states. If we add mercury to a nitric solution of this metal made in the cold and not precipitable by water, aiding the action by the application of

4

heat,



heat, it charges itself with fresh oxide, and becomes capable of being precipitated by water. If we heat for some time the same solution of mercury, the nature of which is not changed by the addition of water, it soon becomes capable of being changed in this manner, as we have thus diminished the proportion of its acid, and increased that of the oxide of mercury, as well as its oxidation, as is proved by the disengagement of nitrous gas which takes place in this experiment; the oxide, on account of its abundance and its surcharge of oxygen, no longer adheres to the acid as it did before, and the water has now the power of separating it, and precipitating it in a white or yellowish powder. This kind of solution forms with the muriatic acid a soluble salt, whilst that of the *neutral nitrate*, or of the acid nitrate of mercury forms an insoluble salt with this acid.

83. The precipitate thus obtained, is not, however, composed of all the oxide of mercury combined with the nitric acid: however large a quantity of water we may employ in order to form it, there always exists in the liquor, after the separation of its deposition, a small portion of oxide combined with the remaining acid. I have also found that the same liquor is capable of yielding crystals of nitrate of mercury, and that its habitudes are in many respects similar to those of the first solution which is indecomposable by water alone. I therefore conclude from all these facts, and from all the facts

facts hitherto known respecting the combination of the nitric acid and mercury, that three species of combination subsist between this acid and the oxide of this metal, as there are three species of sulphates of mercury; and I distinguish three nitrates according to the same principle, and by analogous denominations; viz.

*a. The neutral nitrate of mercury:* that which is yielded by the solution in good condition, or which is not precipitated by water.

*b. The acid nitrate of mercury.* This is obtained by dissolving the first in water, charged with more or less nitric acid, or by adding this acid in any manner to the two other nitrates; it is the most frequent product obtained in the greater number of the solutions of mercury, made for the purposes of pharmacy and of the manufactures.

*c. The nitrate with excess of oxide of mercury:* it exists in the solution which is precipitated by water, or which was formerly denominated in bad condition, or when we treat the two first species by the action of fire; it frequently passes into the state of yellow oxide at the moment of its precipitation, or some instants after, and becomes what was formerly termed *Nitrous Turpeth*.

84. Though these three nitrates resemble each other in several of their properties, and in some of the phenomena that attend their decomposition, they, however, present some differences which it is useful to know and appreciate;

heat, it charges itself with fresh oxide, and becomes capable of being precipitated by water. If we heat for some time the same solution of mercury, the nature of which is not changed by the addition of water, it soon becomes capable of being changed in this manner, as we have thus diminished the proportion of its acid, and increased that of the oxide of mercury, as well as its oxidation, as is proved by the disengagement of nitrous gas which takes place in this experiment; the oxide, on account of its abundance and its surcharge of oxygen, no longer adheres to the acid as it did before, and the water has now the power of separating it, and precipitating it in a white or yellowish powder. This kind of solution forms with the muriatic acid a soluble salt, whilst that of the *neutral nitrate*, or of the acid nitrate of mercury forms an insoluble salt with this acid.

83. The precipitate thus obtained, is not, however, composed of all the oxide of mercury combined with the nitric acid: however large a quantity of water we may employ in order to form it, there always exists in the liquor, after the separation of its deposition, a small portion of oxide combined with the remaining acid. I have also found that the same liquor is capable of yielding crystals of nitrate of mercury, and that its habitudes are in many respects similar to those of the first solution which is indecomposable by water alone. I therefore conclude from all these facts, and from all the facts

facts hitherto known respecting the combination of the nitric acid and mercury, that three species of combination subsist between this acid and the oxide of this metal, as there are three species of sulphates of mercury; and I distinguish three nitrates according to the same principle, and by analogous denominations; viz. :

*a. The neutral nitrate of mercury:* that which is yielded by the solution in good condition, or which is not precipitated by water.

*b. The acid nitrate of mercury.* This is obtained by dissolving the first in water, charged with more or less nitric acid, or by adding this acid in any manner to the two other nitrates; it is the most frequent product obtained in the greater number of the solutions of mercury, made for the purposes of pharmacy and of the manufactures.

*c. The nitrate with excess of oxide of mercury:* it exists in the solution which is precipitated by water, or which was formerly denominated in bad condition, or when we treat the two first species by the action of fire; it frequently passes into the state of yellow oxide at the moment of its precipitation, or some instants after, and becomes what was formerly termed *Nitrous Turpeth*.

84. Though these three nitrates resemble each other in several of their properties, and in some of the phenomena that attend their decomposition, they, however, present some differences which it is useful to know and appreciate;

heat, it charges itself with fresh oxide, and becomes capable of being precipitated by water. If we heat for some time the same solution of mercury, the nature of which is not changed by the addition of water, it soon becomes capable of being changed in this manner, as we have thus diminished the proportion of its acid, and increased that of the oxide of mercury, as well as its oxidation, as is proved by the disengagement of nitrous gas which takes place in this experiment; the oxide, on account of its abundance and its surcharge of oxygen, no longer adheres to the acid as it did before, and the water has now the power of separating it, and precipitating it in a white or yellowish powder. This kind of solution forms with the muriatic acid a soluble salt, whilst that of the *neutral nitrate*, or of the acid nitrate of mercury forms an insoluble salt with this acid.

83. The precipitate thus obtained, is not, however, composed of all the oxide of mercury combined with the nitric acid: however large a quantity of water we may employ in order to form it, there always exists in the liquor, after the separation of its deposition, a small portion of oxide combined with the remaining acid. I have also found that the same liquor is capable of yielding crystals of nitrate of mercury, and that its habitudes are in many respects similar to those of the first solution which is indecomposable by water alone. I therefore conclude from all these facts, and from all the facts

facts hitherto known respecting the combination of the nitric acid and mercury, that three species of combination subsist between this acid and the oxide of this metal, as there are three species of sulphates of mercury; and I distinguish three nitrates according to the same principle, and by analogous denominations; viz.

*a. The neutral nitrate of mercury:* that which is yielded by the solution in good condition, or which is not precipitated by water.

*b. The acid nitrate of mercury.* This is obtained by dissolving the first in water, charged with more or less nitric acid, or by adding this acid in any manner to the two other nitrates; it is the most frequent product obtained in the greater number of the solutions of mercury, made for the purposes of pharmacy and of the manufactures.

*c. The nitrate with excess of oxide of mercury:* it exists in the solution which is precipitated by water, or which was formerly denominated in bad condition, or when we treat the two first species by the action of fire; it frequently passes into the state of yellow oxide at the moment of its precipitation, or some instants after, and becomes what was formerly termed *Nitrous Turpeth*.

84. Though these three nitrates resemble each other in several of their properties, and in some of the phenomena that attend their decomposition, they, however, present some differences which it is useful to know and appreciate;

heat, it charges itself with fresh oxide, and becomes capable of being precipitated by water. If we heat for some time the same solution of mercury, the nature of which is not changed by the addition of water, it soon becomes capable of being changed in this manner, as we have thus diminished the proportion of its acid, and increased that of the oxide of mercury, as well as its oxidation, as is proved by the disengagement of nitrous gas which takes place in this experiment; the oxide, on account of its abundance and its surcharge of oxygen, no longer adheres to the acid as it did before, and the water has now the power of separating it, and precipitating it in a white or yellowish powder. This kind of solution forms with the muriatic acid a soluble salt, whilst that of the *neutral nitrate*, or of the acid nitrate of mercury forms an insoluble salt with this acid.

83. The precipitate thus obtained, is not, however, composed of all the oxide of mercury combined with the nitric acid: however large a quantity of water we may employ in order to form it, there always exists in the liquor, after the separation of its deposition, a small portion of oxide combined with the remaining acid. I have also found that the same liquor is capable of yielding crystals of nitrate of mercury, and that its habitudes are in many respects similar to those of the first solution which is indecomposable by water alone. I therefore conclude from all these facts, and from all the facts

facts hitherto known respecting the combination of the nitric acid and mercury, that three species of combination subsist between this acid and the oxide of this metal, as there are three species of sulphates of mercury; and I distinguish three nitrates according to the same principle, and by analogous denominations; viz.

*a. The neutral nitrate of mercury:* that which is yielded by the solution in good condition, or which is not precipitated by water.

*b. The acid nitrate of mercury.* This is obtained by dissolving the first in water, charged with more or less nitric acid, or by adding this acid in any manner to the two other nitrates; it is the most frequent product obtained in the greater number of the solutions of mercury, made for the purposes of pharmacy and of the manufactures.

*c. The nitrate with excess of oxide of mercury:* it exists in the solution which is precipitated by water, or which was formerly denominated in bad condition, or when we treat the two first species by the action of fire; it frequently passes into the state of yellow oxide at the moment of its precipitation, or some instants after, and becomes what was formerly termed *Nitrous Turpeth*.

84. Though these three nitrates resemble each other in several of their properties, and in some of the phenomena that attend their decomposition, they, however, present some differences which it is useful to know and appreciate;



ciate; this we may do by examining the characters of the real nitrate of mercury, of that which is neutral, which water does not separate from its solution, and which so frequently passes into the acid state, or the state surcharged with oxide, in the different treatments to which it is subjected. We shall soon see that the examination of this will naturally conduct us to the knowledge of the two others. The nitrate of mercury, when placed upon a piece of burning charcoal, detonates feebly, though with a sufficiently bright and brisk flame, if we have taken care to drain it well, or even dried it previously between two pieces of paper: when it is moist, it fuses, becomes black, extinguishes the portion of lighted charcoal which it occupies, throws out small reddish sparks, with a slight decrepitation at its dry sides. The nitrate with excess of acid, boils, becomes liquid very quickly, swells considerably, exhales a large quantity of red vapour, and detonates only in a very feeble manner. If we heat the neutral nitrate of mercury in a crucible, without the contact of combustible matter, it melts, exhales nitrous gas, assumes a deep yellow colour, from which it soon passes to the orange, and from thence to the bright red: in this state it was formerly termed *red precipitate*; in the Methodical Nomenclature it is distinguished by the name of *red oxide of mercury by the nitric acid*. It is frequently prepared, in order to serve the purpose

pose of an escharotic in surgery, by heating and decomposing the nitrate in medicinal phials. When this operation is performed slowly and cautiously, it is obtained in the form of fine brilliant scales of the most beautiful purple colour, and possessing a considerable degree of acrimony. It does not contain any acid when it is well prepared and homogeneous: it is nothing more than a pure red oxide of mercury, in every respect similar to that which is obtained by simple oxidation in the air; and those chemists who have attributed its causticity to the presence of the nitric acid have been mistaken. When it still retains any of this acid, it is because it is not true red precipitate, because it has not been sufficiently heated, and because it still contains some portions of yellow nitrate of mercury, which, together with the portion of red oxide that has been formed, constitute an orange-coloured powder: accordingly, in order to be well prepared, it is necessary that it should be of a beautiful bright purple colour, without mixture of yellow, green, orange, or white. It is very evident that its acrimony depends upon the oxygen and its state of real red oxide. Possibly some advantage may be gained in surgery by not carrying its decomposition quite so far, but by leaving a little nitric acid in it, in order to render it more speedily and powerfully caustic: this, however, is not the true red oxide of the chemists, who ought to continue the process till it contains no more

more acid. This experiment proves, that the white oxide of mercury, united in a saline form with the nitric acid, at a high temperature, decomposes this acid, deprives it of its oxygen, reduces it to the state of oxide of azote, passes itself to the *maximum* of its oxidation, and shows that it is a commencement of this action which takes place whenever we heat the same salt in solution, especially when we cause it to pass from the state of neutral nitrate, to that of nitrate with excess of oxide, and decomposable by water.

85. We see still better what takes place in this decomposition of the nitrate of mercury by the fire, if we perform the experiment in a retort; as long as it is fused and yellow, it yields acidulous water and nitrous gas. From the moment that it has become red, it yields nothing else but oxygen gas, mixed, especially towards the end, with a little azotic gas. In order to obtain this last product, a stronger fire is requisite than for the first. In proportion as the oxygen gas is disengaged, the oxide is reduced, and passes into the state of running mercury, like the oxide *per se*, from which it differs only in the small portion of azotic gas, proceeding from the nitric acid which is found amongst its æriform products. It was with this beautiful experiment that Lavoisier commenced his analysis of the nitric acid, and it was from this that he gradually ascended to the general knowledge of the nature of the other acids, and of the theory of acidification.

86. The

86. The pure neutral nitrate of mercury, when exposed to the air in crystals, is incessantly altered ; it gradually absorbs the atmospheric oxygen ; it passes from the white to the yellow colour ; it cannot be preserved without alteration, except in close vessels ; when it has assumed a yellow colour at its surface, if we attempt to dissolve it in water, a powder separates of the same colour—pale if the water be cold, and deeper if it be boiling. This was the *nitrous turpeth* of Monnet, and its formation is known from what has been said above. This powder is a yellow oxide, retaining a small quantity of nitric acid ; it is a nitrate with excess of oxide of mercury, which passes more easily and speedily into the state of precipitate or red oxide when we heat it, since it has already undergone part of its decomposition as nitrate of mercury. Boiling water renders its colour deeper, not only because it favours its union with the atmospheric oxygen, but also because it separates from it a portion of white nitrate of mercury which is still mixed with it : it is even remarked that this species of *nitrous turpeth* is more oxidated than that formed by the sulphuric acid, as it is much more loaded with oxygen by the first than by the second of these acids. Accordingly, it passes quickly into the state of red oxide by the action of the fire, whilst that which proceeds from the sulphuric acid does not undergo this species of decomposition but with great difficulty.

87. It

more acid. This experiment proves, that the white oxide of mercury, united in a saline form with the nitric acid, at a high temperature, decomposes this acid, deprives it of its oxygen, reduces it to the state of oxide of azote, passes itself to the *maximum* of its oxidation, and shows that it is a commencement of this action which takes place whenever we heat the same salt in solution, especially when we cause it to pass from the state of neutral nitrate, to that of nitrate with excess of oxide, and decomposable by water.

85. We see still better what takes place in this decomposition of the nitrate of mercury by the fire, if we perform the experiment in a retort; as long as it is fused and yellow, it yields acidulous water and nitrous gas. From the moment that it has become red, it yields nothing else but oxygen gas, mixed, especially towards the end, with a little azotic gas. In order to obtain this last product, a stronger fire is requisite than for the first. In proportion as the oxygen gas is disengaged, the oxide is reduced, and passes into the state of running mercury, like the oxide *per se*, from which it differs only in the small portion of azotic gas, proceeding from the nitric acid which is found amongst its æriform products. It was with this beautiful experiment that Lavoisier commenced his analysis of the nitric acid, and it was from this that he gradually ascended to the general knowledge of the nature of the other acids, and of the theory of acidification.

86. The

86. The pure neutral nitrate of mercury, when exposed to the air in crystals, is incessantly altered ; it gradually absorbs the atmospheric oxygen ; it passes from the white to the yellow colour ; it cannot be preserved without alteration, except in close vessels ; when it has assumed a yellow colour at its surface, if we attempt to dissolve it in water, a powder separates of the same colour—pale if the water be cold, and deeper if it be boiling. This was the *nitrous turpeth* of Monnet, and its formation is known from what has been said above. This powder is a yellow oxide, retaining a small quantity of nitric acid ; it is a nitrate with excess of oxide of mercury, which passes more easily and speedily into the state of precipitate or red oxide when we heat it, since it has already undergone part of its decomposition as nitrate of mercury. Boiling water renders its colour deeper, not only because it favours its union with the atmospheric oxygen, but also because it separates from it a portion of white nitrate of mercury which is still mixed with it : it is even remarked that this species of *nitrous turpeth* is more oxidated than that formed by the sulphuric acid, as it is much more loaded with oxygen by the first than by the second of these acids. Accordingly, it passes quickly into the state of red oxide by the action of the fire, whilst that which proceeds from the sulphuric acid does not undergo this species of decomposition but with great difficulty.

87. It

we mix nitrate of mercury and nitrite of ammonia; when the liquor that has been rendered turbid by the addition of water is evaporated, it deposits prismatic crystals with six sides, in proportion as the free ammonia is volatilized. The white precipitate is a neutral salt, a kind of very soluble ammoniaco-mercurial nitrate, with excess of oxide of mercury and of ammonia relatively to the proportion of nitric acid, in which the oxide of mercury appears to be saturated with ammonia, and to form a sort of ammoniacal mercuriate. It is composed in fact of 68,20 of oxide of mercury, 16 of ammonia, and 15,80 of nitric acid and water.

89. The combination of the oxide of mercury with the muriatic acid, forms two very important compounds, with which chemists have occupied themselves a great deal during nearly a century past, and which have particularly been the subject of very fine discoveries in the pneumatic doctrine. We might even assert, that the numerous facts that had been observed and described relative to the salts, previous to the establishment of this doctrine, were more fit to obscure than enlighten the knowledge of their properties. The same holds good with the relation of these facts to the pneumatic doctrine, as with all those that belong the important history of mercury: we find in this exposition, or in the collective view of them, on the one hand, the true foundation of the doctrine of the French chemists, and, on the other, the

the only happy explanation of their causes and effects. This two-fold reason exacts that we should investigate with care, and examine in detail, whatever relates to the union of these substances. The Arabs had some notions concerning the muriates of mercury, in the tenth and eleventh centuries; the alchemists were the first who discovered and described them, amongst the experiments which they made upon the Philosopher's Stone; the pharmacological chemists have particularly occupied themselves with them. Bergman has instituted a long examination of them; but he neither knew their nature, nor suspected their differences, in the year 1769; a period at which, indeed, it was yet impossible to comprehend their differences and their composition. Citizen Berthollet is the first who, after his inquiries respecting the oxygenated muriatic acid, has explained the two principal states of muriate of mercury, and has given a clear account of their distinctive characters according to his ingenious experiments. Since his discoveries, the history of its important combinations has no longer presented any obscurity, but has actually become one of the triumphs of the pneumatic doctrine, as will appear from the exposition which I purpose to give of it.

90. The muriatic acid exerts no action upon mercury, neither in the cold nor with the application of heat. It has however been pretended, that when the acid and the metal are



brought together in the state of vapour, they unite and form a compound saline sublimate. Poulletier-de-la-Salle, the French editor of the Pharmacopœia of London, quotes an experiment, in which he formed corrosive muriate of mercury by this process; but it is evident that only a very small quantity of salt can be obtained in this manner, because the mercury, even in the state of vapour, exerting no action either upon water or the muriatic acid, and not being able to take away oxygen from either of these substances, cannot unite with this acid excepting so far as it may have been oxidated at first by the air of the apparatus; and however large the vessel may be, it is difficult for the metal to become sensibly oxidated by this simple process. Accordingly, all the authors who have indicated this process, agree that it furnishes but very little salt, and that it is more curious than useful.

91. But though the muriatic acid exerts no action upon mercury, it exerts a very strong one upon the oxides of this metal, as was first shown by Margraff in 1746. The manner in which these oxides are attacked by the muriatic acid, varies according to their state of oxidation and the quantity of oxygen they contain. The black oxide is scarcely susceptible of combination with it. The white oxide absorbs it, and forms with it a black muriate, insoluble if it be but little oxidated, and a soluble muriate when it is more oxidated; for many facts prove that the white  
oxide

oxide may vary in its oxidation. The yellow oxide, and particularly the red oxide, when brought in contact with the muriatic acid, produce a sensible effervescence; oxygenated muriatic acid is disengaged, and the oxide, passing to the white colour, unites with the other portion of muriatic acid, so as to form a soluble muriate. These phenomena prove that the attraction between the oxides of mercury and the muriatic acid is very strong, and already indicate that there may be two kinds of combination between these bodies.

92. To this attraction is owing the manner in which this acid acts upon the solutions of mercury in the sulphuric and nitric acids; in general it carries off the oxide of mercury from those acids; but it produces a double effect with these two salts, according to their state. If we treat the yellow sulphate of mercury, or the metallic nitrate precipitable by water, as also the solid yellow nitrate of mercury, with the muriatic acid, we form a soluble muriate, which is termed the *corrosive muriate of mercury*, on account of its excessive acrimony, and sometimes *super-oxygenated muriate of mercury*, on account of the super-abundance of oxygen which the salt thus prepared contains in its composition. If, on the contrary, we treat acid or neutral sulphate of mercury, or the nitrate of mercury not precipitable by water, with this acid, we obtain in the mixed liquors a heavy, curdled, white, insoluble, almost insipid

precipitate, which was formerly termed *sweet mercury*, and which we now distinguish by the name of muriate of mercury, or mild muriate of mercury. It is to be observed, that we obtain the same results, whether we treat the alkaline muriates, and especially muriate of soda, with the sulphates or nitrates of mercury, with the aid of heat, or mix the solutions of these different salts with each other. The only difference in the products is, that the muriates of mercury are volatilized in the first case, and precipitated or obtained by evaporation of the liquors in the second; and as these salts have almost always been prepared in chemistry in the dry way, the products have been termed the *corrosive* or *mild* sublimates.

93. When we place running mercury in contact with liquid oxygenated muriatic acid, the metal is quickly oxidated, and converted into a black and grey powder, which dissolves in this acid when its proportion is sufficiently large. The solution is effected without effervescence or motion, for the mercury, in seizing upon the oxygen, is not here under the necessity of disengaging that principle from another body which is obliged to escape in the form of gas. If the proportion of oxygenated muriatic acid is but scanty, it forms a white powder, which is the *mild mercurial muriate*: if we increase the proportion of the oxygenated acid, the saline powder is re-dissolved, and the liquor then holds *corrosive mercurial muriate* in solution.

It

It is evident that this process, which is very simple and expeditious, is one of the best that can be employed for preparing these salts, though I do not know that it has been practised in the manufactories, in which it will sooner or later be adopted, and in which it will be sufficient to heat in close vessels, adapted for sublimation, a sort of paste or mixture made with sulphate of iron, muriate of soda, oxide of manganese, and running mercury; the doses will be varied, in order to obtain either corrosive muriate, or mild muriate. The theory of these operations is very simple. The sulphate of iron, when heated, gives out its sulphuric acid, which expels the muriatic acid from the marine salt; the latter acid being then transferred to the oxide of manganese, passes into the oxygenated state, soon yields its oxygen to the mercury, and unites with its oxide into the state of *mild muriate*, if the muriatic acid be in but small quantity, or into that of *corrosive muriate*, if its quantity be more considerable; thus it will be sufficient to vary the respective proportions in order to obtain either the one or the other of these products.

94. After what has been said, it is easy to conceive that the oxygenated muriatic acid ought to dissolve all the oxides of mercury much more easily than it does the liquid metal; accordingly there is scarce one of them with which it does not form almost instantaneously, and at the moment of contact, super-oxygenated  
and

and corrosive muriate. Also if we mix this acid with the sulphates of mercury, in whatever state they may be, it converts them all into corrosive muriate; and if we add it to the nitric solutions, it constantly re-dissolves the precipitates which it first produces in them, if we apply it in sufficient quantity; there are even cases in which it does not produce any sensible precipitate in the nitric solution of mercury; sometimes even the solution, when it contains a very highly oxidated oxide of mercury, is not rendered turbid by the ordinary muriatic acid, which then forms corrosive muriate of mercury, a proof that the considerable proportion of oxygen is the only condition necessary to the composition of the super-oxygenated muriate of mercury, and that it is indifferent whether this proportion be furnished by the acid or by the oxide.

95. There are therefore two very different combinations between the muriatic acid, and the oxide of mercury, which have much analogy with those that have been equally distinguished in the history of the sulphate and nitrate of the same metal, depending, as in these, upon the proportion of the oxygen, and which it is essentially necessary to study and particularly describe. We shall soon see that there is even a third with excess of acid. What has already been said concerning the general nature of these muriates, must have been sufficient to prove that they may be prepared in a great number

number of different ways. Authors have also singularly differed from each other with respect to the processes proper for forming these two salts. Wallerius, already in his time, counted ten methods of preparing corrosive sublimate Bergman, in his dissertation written in 1769, has described a great number of them; but there are some that are more generally adopted on account of their simplicity and success. Though I have already indicated a new one which may answer the purpose of the manufacturers of this salt, I shall here describe some of the methods most universally employed for preparing the super-oxygenated muriate of mercury, with which I shall commence their history, and I shall follow the same plan with respect to the sweet muriate of mercury, of which I shall speak hereafter.

96. Most generally, equal parts of desiccated nitrate of mercury, decrepitated muriate of soda, and sulphate of iron calcined to whiteness are mixed together; this mixture is put into a matrafs, two thirds of which must be left empty; and the vessel is placed in a sand-bath, which is heated by degrees till the bottom of the matrafs becomes red-hot. After the apparatus has completely cooled, it is broken to pieces, in order to extract the super-oxygenated and corrosive muriate of mercury, which is found sublimed in the upper part of the matrafs. In this operation, the sulphuric acid disengaged from the sulphate of iron by the  
action

action of the fire decomposes the muriate of soda, whose muriatic acid separates the nitric acid from the nitrate of mercury by taking from it a portion of its oxygen; being thus surcharged with this principle, it unites with the mercurial oxide, with which it forms the corrosive muriate; nitrous gas is disengaged; there remains at the bottom of the vessel a red mass coloured by the oxide of iron, from which sulphate of soda is extracted by means of water. It is asserted, that in the large manufactories in Holland, this product is obtained by exposing to a violent fire a mixture of equal parts of mercury, muriate of soda and sulphate of iron. In this process, which has been indicated by many authors, it appears that the red oxide of iron, the residue of the decomposition of the sulphate, yields a sufficient quantity of oxygen to the muriatic acid to give it the property of transferring itself to the mercury, of combining with it, and reducing it to the state of super-oxygenated muriate. It is also possible to obtain the same salt, by treating with fire mixtures of sulphate of iron, muriate of soda, and different oxides of mercury obtained by precipitating its solutions by an alkali.

97. Boulduc has revived an old process of Kunckel, which also succeeds very well, and which is more simple than the preceding ones: it consists in heating, in a matrafs, a mixture of equal parts of desiccated acid sulphate of mercury.

mercury, and decrepitated muriate of soda. In this case, after the sublimation of the superoxygenated muriate of mercury, pure sulphate of soda remains alone at the bottom of the vessel. This process is that which of all others affords the purest super-oxygenated muriate of mercury; for that from Holland is generally mixed with oxide of iron, or perhaps with muriate of iron, which being decomposed in every sublimation to which it is subjected, always leaves a small quantity of oxide of this metal at the bottom of the subliming vessels. What has been said concerning the sulphate of mercury in the preceding numbers, easily explains the production of the super-oxygenated muriate of mercury which takes place in the process of Kunckel. The strong oxidation of the mercury suffices here in the same manner as when the muriatic acid is placed in contact with an oxide of this metal; it is the case of the yellow sulphate which, as has been explained above, constantly forms super-oxygenated muriate of mercury with the muriatic acid. Monnet assures us, that by treating muriate of soda, in a subliming vessel, with the oxide of mercury precipitated from its nitric solution by means of fixed alkali, we also obtain corrosive sublimate. This experiment, which appears contradictory to the known attractions, requires to be repeated; no chemist, since him who proposed it, has hitherto confirmed its success.



98. We may quickly prepare super-oxygenated muriate of mercury, by pouring oxygenated muriatic acid into a nitric solution of this metal, and evaporating the liquor when it contains the former acid in super-abundance; the acid of the nitre disengages itself in vapour; a part of the oxygenated muriatic acid is volatilized; and the liquid, after sufficient evaporation, and having been suffered to cool, deposits regular and pure crystals of corrosive mercurial muriate. This process, which is equally compendious, and free from danger of vapours, is particularly well adapted for being used in pharmaceutical laboratories; and its product, being very pure, may be especially devoted to medicinal purposes: it is not necessary to sublime the salt obtained in this manner.

99. The oxygenated or super-oxygenated muriate of mercury. If we place a particle of it upon the tongue, it leaves for a long time a very strong and disagreeable sensation of metallic stypticity in the month. This impression, propagated to the fauces and larynx produces a spasmodic constriction of those parts, attended with a strangulating sensation, which lasts several hours, and is extremely painful to nervous persons. Its action upon the stomach and intestines is still much more violent; if it remains for some moments applied to their coats, it corrodes them, penetrates through, or inflames them, and renders them sphacelous; the parts which it has touched falling off in gangrenous

grenous sloughs. Before this terrible effect supervenes, it produces rending pains, nausea, vomiting, convulsions, prostration of strength, and all the formidable symptoms that prognosticate the speedy death which it occasions; it is one of these substances which, after having violently excited the vital action, subsequently weakens and stops them with the greater energy, and by its chemical and deleterious action causes the parts which it touches to pass rapidly into mortification. The destructive effects of a powerful caustic are easily distinguishable in the traces which it leaves behind after its action. The ancient chemists, attributed these effects to the presence of the acid. Nothing however can be more erroneous than this opinion, and at present every thing proves that this action is owing to the state of the oxidation of the mercury. From these facts we may judge how dangerous it is to prescribe the super-oxygenated muriate in the solid form, as is nevertheless so inconsiderately done by ignorant persons.

100. The form of the super-oxygenated muriate of mercury is extremely various. By sublimation it affords a great number of needles or very fine prisms, lying close against each other, which appear to be tetrahedral and compressed. Authors have compared them to the beards of feathers and to sword-blades. When crystallized by means of water, it is either in cubes, or in oblique parallelopipedons, or in very small prisms.

prisms. Sometimes it affords quadrangular prisms, with sides alternately narrow and broad, terminated by cuneiform summits, and presenting two inclined planes. It is said to have been also obtained in very regular hexahedral prisms. In general it presents sharp points at its extremities; and chemists have made an improper application of this form, in order to compare it with sword or dagger-points, imagining thereby to explain its effects upon the animal economy, which is very far from being the product of any mechanical action. Philosophers have no less varied from each other in appreciating its specific gravity. In the *Physique* of Coste, we find it estimated at 6,325, whilst Muschenbroeck makes it amount to 8,000.

101. This salt possesses a considerable degree of volatility, on which account it has received the name of *corrosive sublimate*. It is easily reduced to the state of vapour in the air, and this vapour is extremely dangerous when received into the lungs. It is not decomposable by the action of caloric, nor does it yield oxygen gas, though some modern authors have asserted that it does. Were this the case, it would become mild muriate of mercury, whereas, it is well known, that it does not undergo this change by the action of fire. It is unalterable by the air, in which, however, it loses something of its transparency, and becomes white, opaque, and pulverulent at its surface. It is soluble in about 20 parts of cold water; hot water dissolves

olves a little more of it ; however, it crystallizes very little by refrigeration, and regular crystals are obtained only by slow evaporation. The sulphuric acid renders it much more soluble, but it precipitates it by refrigeration, in an unaltered state, which accords with the decomposition of the sulphate of mercury by the muriatic acid and the muriates. The muriatic acid produces the same effect upon the super-oxygenated muriate of mercury, and adheres to it sensibly, producing a variation in its crystallizability; for it is afterwards obtained in no other form than that of small needles, or else it can no longer be made to crystallize: the nitric acid, in dissolving it, extricates vapours of oxygenated muriatic acid, according to Bergman, who, however, assures us, that it may afterwards be obtained in the crystalline form, without having lost either weight or its other properties.

102. All the earthy and alkaline substances possess the power of decomposing the super-oxygenated muriate of mercury, and precipitating its solution. Bergman observes, that the fixed alkalis generally produce a red precipitate from it, but that this precipitate varies according to the proportion of the acid, which he believes to be variable, and that it approaches to white when the quantity of the acid is very abundant. It is to be observed, on this head, that well neutralized super-oxygenated muriate of mercury, possessing the property of turning

of muriatic acid, and 0,03 of ammonia; there remained in the supernatant liquor the pure muriate of ammonia. The great difference between the precipitation of the super-oxygenated muriate of mercury, and that of the sulphate and nitrate of the same metal, consists in the circumstance that there is no oxide of mercury reduced, and that the whole of the precipitate constitutes a triple insoluble salt. This shows that the ammonia, without decomposing the super-oxygenated muriate of mercury, and without separating oxide from it, forms a triple salt in which this oxide, more abundant than in the corrosive sublimate, is saturated by the ammonia, which it at the same time saturates after the manner of an acid.

105. All the precipitations of the super-oxygenated muriate of mercury by the alkaline substances, conduct us to the knowledge of the proportions of the principles of this salt, and yet they have not hitherto been accurately determined. According to Tachenius, the mercury is to the acid as  $3\frac{1}{4}$  to 1. Lemery gives this proportion: :  $5\frac{1}{4}$  : 1. Bergman, who seems to come nearest to the truth, says, in his *Humid Docimasia*, that 100 parts of super-oxygenated muriate of mercury contain 24,5 of muriatic acid, and 75,5 of mercury; but there is an error in this estimate; for if this salt contains 0,75 of running mercury, as Bergman announces, it is evident that we must subtract

tract from the 24,5 of acid the proportion of oxygen, which cannot be computed at less than between 9 and 12 to the 75,5 of metal: 100 parts of the super-oxygenated muriate of mercury, must therefore contain at the highest computation 15,5 of muriatic acid, or at the lowest 12,5. It must be left to subsequent experiments to determine in how far this estimate is deficient, which as yet can be only an approximation to the truth.

106. The super-oxygenated muriate of mercury is decomposed by water charged with sulphurated hydrogen gas, as also by the hydrogenated sulphurets and the alkaline hydro-sulphurets. These combustible mixtures all yield alike a precipitate of black sulphurated oxide of mercury, which passes more or less speedily into the red colour, and the fetid smell of the hydrogenated sulphurets is destroyed. By means of this process we also form a black or red sulphurated oxide in the humid way. Phosphorus, which easily decomposes the nitrate of mercury when it is kept for some time immersed in its solution, does not so easily effect the decomposition of the super-oxygenated muriate of mercury, because its particles possess a stronger adhesion than those of the nitrate. The phosphorated hydrogen gas precipitates it in a black powder. Carbon exerts no action upon this salt, neither in the cold nor in heat.

107. Amongst the salts which have hitherto been examined, the ammoniacal muriate is the

only one with whose effects upon the super-oxygenated muriate of mercury, we are well acquainted. This combination has long since been discovered and examined by the alchemists, who termed it *Sal Alembroth*, or *Sal Sapientiae*, as they placed great reliance upon its properties for the attainment of their grand object, and whatever flattered them, in this respect, with the chimerical hope of success, was decorated in their language as well as in their notions with a pompous title. This is perhaps the first triple salt that was discovered and known. The muriate of ammonia renders the super-oxygenated muriate of mercury much more soluble than it naturally is; for one part of the first, dissolved in three of water, renders almost five of the second soluble in the same fluid, though these five parts of the latter would require nearly 100 parts of water for their solution, if alone. In this experiment, heat is produced on account of the density which the liquid assumes, and this afterwards becomes solid on cooling: there is, therefore, reason to believe, that its liquid state depends upon the elevation of temperature which accompanies its solution. The ammoniaco-mercurial muriate is equally formed, or rather it is not decomposed by sublimation, and the two combined salts of which it is composed, preserve their mutual adhesion and combination in the volatilization to which they are subjected. When we treat this triple salt, formed with equal parts of the

two salts, with an alkaline carbonate, we obtain the first triple salt in a white precipitate, formed in other proportions, which has been described above in the history of the precipitation of the super-oxygenated muriate of mercury by ammonia. In pharmacy, the salt obtained by this last mentioned process is termed *white precipitate of mercury*, though this name is also given to the sweet muriate of mercury formed by pouring the muriatic acid into a solution of nitrate of mercury; this last precipitate is also termed *cosmetic mercury*, or *milk of mercury*. In order to distinguish this species of white precipitate or triple muriate of mercury and ammonia, from that which is soluble, and which was formerly termed *Sal Alembroth*, I designate the latter by the name of *soluble ammoniaco-mercurial muriate*, and the former by that of *insoluble mercurio-ammoniacal muriate*.

108. The super-oxygenated muriate of mercury is decomposable in heat by many metallic substances, which have more attraction for oxygen than mercury has. These decompositions yield, some of them mercury reduced into the liquid form, others, metallic muriates, sometimes super-oxygenated, which are all more or less volatile, concreting in the cold, fusible in a gentle heat, decomposable by water: they were formerly termed metallic butters; they are more or less useful in the arts or in pharmacy. It is also remarked, that these decompositions of the super-oxygenated muriate of mercury are



effected by the sulphurets or the sulphurated oxides of the same metals, and instead of having then running mercury, we obtain red sulphurated oxide of mercury. It is further to be observed, that the oxides of these metals alone do not in general decompose the super-oxygenated muriate of mercury; for this decomposition being effected only by the attraction of these metals for the oxygen which they take away from the mercury, they can no longer produce this effect when they are saturated with it. Thus the oxide of arsenic, and those of bismuth and antimony, do not by themselves decompose the super-oxygenated muriate of mercury, though their metals decompose it; but these oxides, when combined with sulphur, decompose it, because the oxide of mercury is attracted by the sulphur; whilst the muriatic acid on its part attracts each of these oxides, which it converts into volatile muriates.

109. This general theory of the action of the metals, and of the metallic sulphurets upon the super-oxygenated muriate of mercury, is easily applicable to each of the particular decompositions that are effected upon this salt by these bodies.

a. When we distil, by a gentle heat, two parts of super-oxygenated muriate of mercury with one part of metallic arsenic, previously pulverized, and well mixed in a glass mortar, there passes into the receiver a substance of the consistence of oil and transparent, part of which  
fixes

fixes itself into a species of jelly, which has been termed *corrosive oil*, or *butter of arsenic*, this is the sublimed muriate of arsenic; the running mercury passes over afterwards. The arsenical muriate is decomposed by water, which precipitates arsenious acid from it. This acrid and caustic salt speedily destroys the organs of animals.

*b.* Equal parts of sulphurated oxide of arsenic and super-oxygenated muriate of mercury, yield by distillation muriate of arsenic, and red sulphurated oxide of mercury, which was formerly termed *cinnabar of arsenic*.

c. Two parts of corrosive muriate of mercury, and one part of bismuth, distilled together, produce a thick liquid, partly congealed into the consistence of a very fusible fat, precipitable by water, distinguished by the name of *butter of bismuth*, and which is the sublimed muriate of bismuth. The mercury remains combined with a portion of the bismuth in a crystallized amalgama, or is partly volatilized. Poli, who had described this experiment in the year 1713, in the Memoirs of the Academy, asserts that when this *butter of bismuth* is repeatedly distilled, there remains in the retort a shining powder, of the colour of mother of pearl, unctuous, soft to the touch, and of so beautiful an appearance, that he has proposed it to be used by painters.

d. When one part of pulverized antimony is triturated with two parts of super-oxygenated

muriate of mercury, heat is excited which indicates a very violent action between the two substances, and proceeds merely from the fixation of the oxygen of the mercury in the antimony. This mixture, distilled in a glass retort, with a gentle heat, yields a thick liquid, of a greasy appearance, and slightly fuming, which fixes itself in the receiver, and in the neck of the retort, to the beak of which it hangs like a stalactite, in a greyish white mass, frequently in a crystalline form, and radiated at its surface. This product weighs more than the antimony by one fourth: it was formerly termed *butter of antimony*; we now call it *sublimed muriate of antimony*. When this salt has passed over, and the operation is stopped, the residue is then a sort of amalgam of antimony; a portion of the latter metal floats at the top in the form of a grey powder. By continuing the application of the heat, and changing the receiver, after having obtained the muriate of antimony, we obtain running mercury. If this operation be performed with the sulphuret of antimony, there sublimes after the antimoniated muriate, and by the application of a strong heat, a violet-coloured sulphurated oxide of mercury, which does not contain a sufficiency of oxygen to exhibit the bright red colour, and which was formerly termed sublimed cinnabar of antimony. This process does not succeed unless with a por-

a porcelain retort, and a great degree of heat. The sublimed muriate of antimony, prepared by either of these processes, crystallizes, by slow refrigeration, into very thick parallelo-pipedons. It is a violent caustic, which corrodes and burns the organs of animals, and is employed externally with great success, for destroying different kinds of virus introduced into the skin, and especially the hydrophobic virus introduced by the bite of a rabid animal. The sublimed muriate of antimony becomes coloured by exposure to the light and air; it melts and runs like fat in a gentle heat; it attracts the humidity of the atmosphere, and is resolved into a thick oleaginous fluid; it is decomposed and precipitated by water which separates from it a very white oxide of antimony, which formerly was known by the very improper name of *mercury of life*, and that of *powder of algaroth*, after Algarothi an Italian physician, who first recommended and employed it as an emetic and purgative remedy. The water, after having precipitated it, retains a portion, dissolved in the muriatic acid which it takes up. The nitric acid dissolves the sublimed muriate of antimony, with heat, effervescence and extrication of nitrous gas; it forms a nitro-muriate of antimony at first in a red liquid, which soon deposits a white powder or magma, when this solution is evaporated to dryness, and  
after-

afterwards its weight of nitric acid added, and again evaporated. When this operation has been thrice repeated, and the residue lastly heated in a crucible, which is kept ignited for the space of half an hour, we obtain an oxide white at the top, and of a light rose colour at the bottom, which was formerly termed *bexoar mineral*, and is analogous to the oxide formed by nitre. We have seen that antimony, dissolved immediately in the muriatic acid, may afford, by sublimation, the same product, which is still better obtained by means of the oxygenated muriatic acid; but it has always been prepared by the decomposition of the super-oxygenated muriate of mercury.

110. One of the most singular properties which the super-oxygenated muriate of mercury has presented to chemists, with respect to the action which the metals exercise upon it, is its union with running mercury, with which it forms the combination known by the name of *sweet mercury*, or *mild sublimate* of mercury. The preparation of this kind of salt was considered as an important secret at the beginning of the 17th century. Crolius made a great boast of keeping this secret concealed. In 1608, Beguin described it with great accuracy, in his *Tyrocinium Chemicum*, by the name of *draco mitigatus*, on account of the mildness which was by that means communicated to the corrosive sublimate. It became much more generally

rally known under the name of the *Panchymagogue of Quercetan*, or of *Duchefne*. Neuman was the first who gave it the appellation of *Mercurius dulcis*. It has been known at different periods under the denominations of *Sweet sublimate*, *Aquila mitigata*, *aquila alba*, *manna metallorum*, *panacea*, *calomelas*, according to the different methods of preparing it. Citizen Baumé, Bergman, and Scheele, are the authors who have treated the best concerning this salt. The pneumatic doctrine has given an accurate idea of its nature, by defining it as a simple muriate of mercury, and thus opposing it to the former, denominated the super-oxygenated muriate of mercury.

111. When we triturate this last salt with running mercury, we soon perceive that this metal quickly disappears, that it is extinguished in the salt, and that it assumes a blackish grey colour. This operation was formerly performed in a mortar of glass, mercury being added till it ceased to be extinguished; and it was remarked, that in this manner it absorbed it to the amount of three fourths of its weight. The mixture was then put into retorts, matrasjes, or simple phials, two thirds of which were left empty; these were placed in a sand-bath, and strongly heated, till the whole mass was sublimed: the vessels being then suffered perfectly to cool, the acrid powder of corrosive sublimate which was first sublimed, and a blackish powder which soiled the colour of the product, were separated.

Some

Some authors directed the sublimation to be performed three successive times ; and it was after these three sublimateations that it was termed *aquila alba*. Others directed it to be triturated again with a fresh quantity of mercury after each sublimation. Six of these successive operations formed the *calomel* or *calomelas* ; an absurd denomination, as has been justly remarked by Bergman, who says, that it has, however, been adopted in Sweden for the sweet mercury after its first sublimation. According to Malouin, one Labruné carried these fastidious operations still farther ; and it was by a series of nine successive sublimateations that he directed the mercurial panacea to be prepared.

112. This process is so tedious, and attended with so many inconveniences, especially the danger of the acrid dust which rises during the trituration, notwithstanding the precaution used by the workmen of tying a napkin round their faces, that chemists have used their utmost endeavours to improve and correct it. Citizen Baumé has recommended to pour a small quantity of water upon the substances that are triturated, to use a mortar of porphyry, and to wash the sublimed product once in hot-water, in order to dissolve the portion of super-oxygenated or corrosive muriate which is contained in it. Others have proposed to employ the grey oxide precipitated from the nitrate of mercury by ammonia, instead of mercury, in order to diminish  
the

the duration and difficulties of the extinction. Citizen Bailleau has directed us to form a paste with the super-oxygenated muriate and water, and to triturate it with running mercury, which is extinguished in it very easily, and in the space of half an hour, without throwing up the corrosive dust, afterwards to digest the substance with a gentle heat, which whitens it and promotes the combination, and lastly, to sublime the mixture once: this, according to him, is sufficient for obtaining the product in a very pure state.

113. The theory of this operation is extremely plain and simple. The super-oxygenated muriate of mercury very easily yields a portion of its oxygen to the mercury: hence the quick extinction of this metal, and the grey colour which the mixture assumes, as is the case when mercury is triturated with its red oxide: the action between the two bodies ceases after the extinction, which is limited in its duration as well as in its proportions; for as soon as the distribution of the oxygen between the oxide of the corrosive muriate of mercury and the  $\frac{1}{4}$  of its weight of mercury has been completed, a permanent equilibrium is established. The mixture has already lost its acrimony and solubility; but there is not yet any very intimate combination between the two portions of oxide and that of the acid; the heat completes the reciprocal union, which is perfect after one sublimation; all the sublimations which are performed after this, and still more so the new triturations



turations with mercury, are useless: and the washing with hot water is perfectly sufficient to carry away the small proportion of corrosive muriate that may still remain in it; the addition of a small quantity of muriate of ammonia to this lixivium, still more certainly insures the separation of the corrosive salt, by the tendency which it has to unite with it into a triple salt, whilst it does not exert the same action upon the sweet muriate of mercury.

114. It is easy to conceive why the super-oxygenated muriate of mercury, united by this process with  $\frac{1}{4}$  of mercury, loses its corrosive property, since we have so many proofs that the oxygen, being proportionally diminished by its distribution in a larger quantity of mercury to which it more strongly adheres, must greatly diminish the taste and acrimony of this compound. It is no less easy to perceive, that as the difference between these two salts depends in a great measure upon the quantity of oxygen being less abundant and more strongly adhering, as also upon the proportion of the muriatic acid being smaller in the second than in the first; whenever we shall combine muriatic acid with mercury but little oxidated, and it forms in its combination an insoluble salt, we shall obtain sweet muriate of mercury. Lemery has also remarked, that the ordinary white precipitate, formed by the mixture of a solution of muriate of soda with a solution of nitrate of mercury, required only to be sublimed in order  
to

to be sweet mercury; and Neuman had likewise perceived a resemblance between these two substances. It was upon this identity that Scheele founded the process which he gave for preparing the mild muriate of mercury in the humid way. He advises us to dissolve mercury in its weight of nitric acid, with the aid of a gentle heat, and to make a solution of a quantity of muriate of soda, amounting to a little more than half the dose of mercury, in thirty-two times its weight of boiling water, to mix the two hot liquors, to keep the mixture continually stirring, to let the precipitate be deposited, to decant the clear liquor that floats above it, to edulcorate it with hot water till this passes off insipid, to throw the whole upon a filtre, and to dry it with a gentle heat. This muriate of mercury is as mild and as pure as that which is prepared by trituration, extinction, and sublimation; the process is simple, easy, and sure; it has none of the inconveniences of the other, and it is greatly preferable to it.

115. The properties of the mild muriate of mercury are essentially different from those of the corrosive muriate. It has but very little taste, and in the solid form it acts only as a gentle purgative, whilst the other is a poison of the most violent energy. Its specific gravity is 12,353, according to Muschenbroeck, who has observed that its specific gravity was diminished in proportion as it was sublimed; it turns black by long exposure to the light; it is luminous and phos-

phosphorescent when rubbed in the dark. It is more difficult to be volatilized and sublimed than the super-oxygenated muriate of mercury; accordingly, this rises before the former, when mixed with it, and is found at the top in the subliming apparatus. When slowly and cautiously sublimed, it yields crystals in tetrahedral prisms, terminated by pyramids with four sides; sometimes there are two quadrangular pyramids, united base to base, so as to form a very long and pointed octahedron. It is so little soluble, that, according to the experiments of Rouelle, made in 1754, it requires 1152 parts of boiling water for its solution. This solution turns the syrup of violets green, is rendered slightly turbid by the fixed alkalis, and assumes an opal colour, without forming any sensible precipitate when ammonia is added. It receives a brown tinge by the contact of lime-water, ammonia, and the fixed alkalis. It does not combine with the muriate of ammonia, which serves to separate from it the super-oxygenated muriate with which this last salt so easily combines. It can neither absorb more mercury than it contains, nor exist in a mean state of oxidation between its own and that of the super-oxygenated mercurial muriate; a state which some authors have admitted gratuitously, and without proofs; neither can it unite with the latter, which is easily separated from it by volatilization; the nitric acid does not convert it into corrosive muriate; this change it undergoes only when  
treated

treated with an equal weight of muriate of soda and twice its weight of sulphate of iron ; the addition of oxygenated muriatic acid dissolves it instantaneously, and converts it into super-oxygenated muriate. The proportions of the principles of the mild muriate of mercury are not, as yet, well known. Lemery asserted, that its acid was to mercury as 1 to  $6\frac{2}{3}$ .

116. In comparison with what has just been explained, concerning the action of the three first acids upon mercury, very little is known of that which the other acids exert upon it. The phosphoric acid cannot act upon mercury, but it combines with its oxide. The only good way of effecting this combination is by precipitating nitrate of mercury with a solution of alkaline phosphate ; a white precipitate of insoluble mercurial phosphate is immediately formed : the greater part of the animal liquids yield this species of salt mixed with mild muriate of mercury, when nitrate of mercury is added to them. The phosphate of mercury is phosphorescent and luminous when rubbed in the dark ; when exposed to the fire, and especially with a little charcoal, it yields phosphorus. It has been pretended, that corrosive sublimate is decomposed in the human body by the phosphates which it contains ; but no chemical proof has been given of this assertion.

117. The fluoric acid exerts no action upon mercury, but it combines with its oxide, and the soluble fluates mixed with the nitrate of mercury,

mercury, form in it a white precipitate of mercurial fluatc, the properties of which have not yet been examined.

118. The boracic acid also exerts no action upon mercury in a direct manner; but by mixing the solutions of soluble borates with the nitric solution of mercury, we obtain a yellowish precipitate of mercurial borate, which was first described by Citizen Monnet. By slowly evaporating the super-natant liquor, a new portion of this salt is separated in the form of shining pellicles. In order to obtain the borate of mercury pure, we must not employ the borax of commerce; for the soda, which this contains in excess, gives a portion of brick-coloured oxide of mercury which is much more acrid than the borate of mercury; we must, therefore, take borate saturated with boracic acid. The mercurial borate acquires a greenish colour by exposure to the air; the muriate of ammonia renders it soluble and crystallizable; lime-water precipitates it in a red powder. It has been proposed and adopted for medicinal use.

119. The carbonic acid exerts no action upon mercury, but we may combine it with its oxide, by precipitating its solutions in the other acids by means of the alkaline carbonates. These carbonates are white or but little coloured; they do not acquire a deeper tinge by exposure to the air, like those which have been made by the pure or caustic alkalis. However, they assume a brown tinge in drying, and it is on  
account

account of this tinge, which the oxide of mercury, formed by the action of fire alone, sometimes assumes as it cools in the air, that this oxide is supposed to be charged at that time, or in the case of its acquiring the brown colour, with carbonic acid. This compound is not soluble in water; the preceding acids expel the carbonic acid from it in the form of gas with effervescence.

120. The combinations of the four known metallic acids with the oxide of mercury have not yet been accurately examined; it is only known that these acids in general exert but very little action upon mercury, since this metal cannot absorb oxygen from them. Scheele has indicated some of the properties of the arseniate, tungstate, and molybdate of mercury, which are prepared by pouring into the nitric solution of this metal alkaline or soluble salts formed by these acids.

A. The arsenic acid, treated, in a retort with mercury, is partly decomposed by this metal; arsenious acid, running mercury and a small quantity of yellow oxide of mercury are sublimed; there remains in the retort a yellow mass, not fused, insoluble in water and in the sulphuric and nitric acids, soluble in the muriatic acid, and yielding afterwards, by the evaporation and sublimation of this solution, superoxygenated muriate of mercury and fused arsenic acid; the mercury decomposed a part of this acid by depriving it of a portion of its

VOL. V.                      K k                      oxygen,

oxygen, and leaving it that which forms the arsenious acid; the oxide of mercury that was formed united with the other portion of this acid into an arseniate of mercury, which the muriatic acid then decomposed, and in the mercury of which it found a sufficient quantity of oxygen to change it to the state of corrosive muriate.

B. The arsenic acid precipitates the sulphate and the nitrate of mercury of a white colour; it decomposes the mild mercurial muriate, and converts it into corrosive muriate; it produces no effect upon the latter, nor upon the oxide of mercury.

C. The tungstic and molybdic acids precipitate the nitric solution of mercury of a white colour; it appears that the tungstate and molybdate of mercury are white and insoluble.

D. The chromic acid, combined with the oxide of mercury by the addition of the solution of an alkaline chromate with that of the nitrate of mercury, forms an insoluble precipitate of a very lively and brilliant purple colour, which Citizen Vauquelin, who discovered it, thinks might become of great utility in painting.

#### I. *Action upon the Alkaline Bases and the Salts.*

121. MERCURY is not susceptible of alteration by the alkaline earths and the alkalis. In the experiments of Westendorf and Wallerius upon this metal, pretended to be combined with the  
fixed

fixed alkalis by fusion in crucibles, it appears that they mistook the union of an oxide of iron with those bases for that of the mercury, which, in reality, does not suffer any alteration.

122. The case is not the same with the oxides of mercury; besides the fact, that several of them are susceptible of combining with the alkalis in general, and of forming with them compounds in which these oxides seem to act the part of acids, ammonia exerts upon those burned substances a very remarkable action, which has already been indicated in the account of the precipitations of the mercurial salts, but which ought again to be considered in this place. We have already seen, that ammonia poured upon the white, yellow, and red oxides of mercury, turns them black, produces an extrication of azotic gas with noise and effervescence, and that this is owing to the reciprocal decomposition of these two substances, which form water by the union of the hydrogen of the ammonia with the oxygen of the oxide, whilst the azote, having become free, is disengaged in the form of gas: but there is another chemical effect which a circumstance led me to discover in this action. I had remarked, that the effervescence and the extrication of azotic gas were but little sensible, and did not appear to accord with the proportion of reduced oxides. I therefore examined the product of this operation with greater attention; and by evaporating the



lixivium of a mixture of red oxide of mercury and of ammonia in excess, which had in part effected its reduction, I obtained a real triple salt, an *ammoniaco-mercurial nitrate*: nitric acid is consequently formed by the effect of this decomposition. The oxygen of the oxide of mercury divides itself between the two principles of the ammonia: one portion forms water with its hydrogen, another constitutes with its azote, nitric acid, which, uniting with a part of the oxide, and of the ammonia that have not been decomposed, gives rise to the *ammoniaco-mercurial nitrate* which is obtained. This phenomenon accords with that which takes place when we cause ammoniacal gas to pass into a red hot tube containing oxide of manganese: it recurs also in the decompositions of the sulphates of mercury by ammonia, in which we always meet with a small quantity of *ammoniaco-mercurial nitrate*, when we examine the products of the experiment with attention. The property which ammonia possesses of speedily reducing the oxides of mercury, suggested to me the idea of employing it for cleaning and purifying, in some degree, the surfaces of the hydrargyro-pneumatic vessels. When the mercury has been soiled and oxidated by the saline gases, and especially by the oxygenated muriatic acid gas, I restore it to all its natural lustre and purity by pouring and moving ammonia upon its surface, by the aid of filtering paper, upon which

which it immediately assumes its usual brilliancy and colour.

123. Mercury and its oxides exert no action upon the earthy and alkaline sulphates, nitrates, phosphates, nor upon any other kind of salts, if we except the muriates. It has already been observed, that Citizen Monnet had indicated the decomposition of the muriate of soda by the oxide of mercury, and the formation of corrosive muriate of mercury. Lagaraye, in a kind of empirical medicinal preparation, has even succeeded in decomposing the muriate of ammonia by means of running mercury, as Macquer assured himself by a scrupulous examination of the process for his *mercurial tincture*. Lagaraye triturated one part of running mercury with four parts of muriate of ammonia in a marble mortar, moistening the mixture with a little water till the extinction was complete; he afterwards exposed the mixture for several weeks to the air, agitating it from time to time; he triturated it a-new, and heated it then in a matrafs with some good alcohol, which he even caused to boil slightly; the alcohol assumed a yellow colour, and it whitened a plate of copper. Macquer was convinced that this liquor contained super-oxygenated muriate of mercury in solution, that by the operation of time, the muriate of ammonia had been decomposed by the mercury which had become oxidated, and that a species of ammoniaco-mercurial muriate or *Sal Alembroth* had been formed.

K. Uses.

K. *Uses.*

124. THERE are few metallic substances that exceed mercury in utility. In physics it is employed, in its metallic form, in the construction of meteorological instruments, and a great number of machines; in the arts, it is employed, in the same form, for gilding, silvering of glass mirrors, and in metallurgical operations: its solutions are used in dyeing.

125. In chemistry, it is applied to a great variety of uses, all equally important. Besides the experiments in which it is employed for demonstrating the principal truths of this science, it has become of indispensable necessity for furnishing the vessels destined to collect, preserve, and combine the elastic fluids of a saline nature. These apparatuses are termed hydro-pneumatic vessels. It is no less useful for luting or closing moveable tubulatures, for producing compression. Lavoisier had already attempted to use it for supplying the place of the lutes, by means of which, the vessels are closed, and which so frequently occasion inconvenience, error, and inaccuracy in experiments. It is of great utility to anatomists in their most delicate and difficult injections, such as those of the lymphatic and absorbent systems in all animals, and of the tracheal system of insects and worms.

126. It is of equal importance for medicinal purposes. Since its salutary effects in cutaneous diseases,

diseases, and its specific operation in syphilitic affections have been known, it has been exhibited in a great variety of forms and preparations. As these properties were attributed to the metal itself, endeavours were made to soften or modify it; but scarcely any thing more was done, than, on the contrary, to give it, unknowingly, a greater degree of activity, by combining with oxygen, which is the true cause of its effects. In general, mercury ought to be considered, in its medicinal preparation, as nothing more than an oxiphorous substance, as a substance which carries oxygen into the animal economy, which readily imparts it to the fluids and solids, and the varieties of these preparations under the relation of the quantity of this principle which they contain. The least oxidated compounds have but little activity: such are the black oxides of mercury which are prepared in the numerous processes of extinction, by the addition of mucilages, syrups, honey, jellies, or animal humours, such as saliva, the fats.

In a second class are to be ranked the mercurial salts, of little solubility, the oxide of which, being either but little oxidated, or in some respect confined by acids, does not nearly exert all its energy upon the animal fibre or humours: such are the mild mercury, the carbonate, the borate, and the phosphate of mercury.

In a third class we are to rank the oxides of mercury united with sulphur, either black, or red, which act but slightly, or only when  
in

in the form of vapour upon the animal economy.

Lastly, a fourth class of these mercurial remedies is formed of oxides the most highly charged with oxygen, either alone or combined with the acids; such as the different precipitates, yellow, white, red, and the super-oxygenated fulphate, nitrate and muriate of mercury. These are violent caustics; they burn and destroy the organs; they are employed externally as detergents, and internally as powerful remedies which must be administered with great prudence, and which only the skilful practitioner should be permitted to employ, with that circumspection which ought to distinguish the true physician.

127. What proves that the action of the mercurial preparations is owing to the oxygen which they contain, to the separation of this principle, and its being transferred to the organs, and the humours of animals, is that the oxides of which they consist, become black, and are reduced in the internal part of the body, and that running mercury is frequently found in the internal cavities of the body, in the lymphatic system, and in the bones, themselves, after a mercurial course of a longer or shorter duration.

123. What I have here been able only to announce and present to the reader in general terms, has been very fully treated in the treatise of my friend Dr. Schwediauer, a work  
the

the most complete, the most original, and the most philosophical that has yet been published concerning the syphilitic affections. Several chapters of this excellent work exhibit all the new facts which I have presented for several years past, relative to the properties of this medicine as an oxipherous remedy; data which this able physician has confirmed by his own observations. It concludes with a methodical table of these preparations, intitled *pharmacopoeia syphilitica*: where the reader will see how well the author has availed himself of the present state of chemical knowledge in the classification of these remedies.

## ARTICLE XV.

## Of Zinc.



## A. Literary History.

1. ACCORDING to Bergman, zinc was not known to the ancients. Paracelsus is the first chemist who has treated of it, and who gave it the name which it bears. Agricola has since termed it *contre-feyne*, and Boyle, *speltrum*. Albertus Magnus, who died in the year 1280, makes very distinct mention of it; he knew that it was combustible, and inflammable, and that it coloured metals. It appears

pears that zinc has for a long period back been extracted from its ores in the East Indies, as was first observed by Jungius in the year 1647. It is brought from those parts under the name of *tutenague*. Without being particularly acquainted with it, and distinguishing it accurately from other metals, the Greeks seem also to have employed it, as it is said to have constituted a part of the famous Corinthian brass.

2. It is not known by what process the Chinese obtain this metal, which they employ in a great number of alloys: it is believed, that they extract it by distillation. Henckel asserted, in 1721, in his *Pyrilogia*, that zinc might be extracted from calamine. In 1742, Schwab extracted it by distillation. Margraff occupied himself with this extraction in 1746.

3. Lemery considered zinc as a species of bismuth. Glauber, with the alchemists, considered it as an immature solar sulphur; Homberg took it for a mixture of iron and tin; Kunckel, for coagulated mercury; Schlutter, for tin rendered brittle by sulphur. In short, it is not more than fifty years since it has been known to be a metal, *sui generis*, pure, well characterized, and different from all other metals.

4. The chemists whom I have just quoted, as well as all those whose works have embraced the whole or entire system of natural bodies, have successively examined zinc and dis-

discovered its properties. Hellot, Pott, Malouin, Laffonne, Monnet, Baumé, Bergman, are those who have successively instituted particular investigations respecting this interesting metal. Gellert has treated of its alloys; Malouin has compared it with tin; Bergman has given an extensive and very detailed docimasia of its ores. Citizen Sage, first ascertained its ductility; Dehne, and Citizen Guyton, have particularly directed their attention to its combination with sulphur. Gaubius has ascertained several of the properties of its oxide; Macquer has dwelt upon its economical uses; Pelletier has accurately described its union with phosphorus.

5. Since the revolution and renovation of chemistry, effected by the doctrine of the French, no new researches nor consecutive series of investigations have been made respecting zinc; nevertheless the exact data and bases of this doctrine have rendered our knowledge of the chemical properties of this metal much more clear and precise; so that its history is much more easy and more methodical than it was previous to this period, and all the facts which appertain to it, are linked together by much more intimate relations, than they had been during the reign of the theory of phlogiston.

6. It will however appear, from the details which will form the subject of this article, that all which relates to zinc is not yet entirely and completely discovered, that many  
discoveries



discoveries still remain to be expected, and that it may still afford a subject to able chemists for valuable researches, especially with the new instruments which we now possess.

### B. *Physical Properties.*

7. PURE zinc is of a brilliant white colour, with a blueish tinge, which is very perceptible in its metallic state, presenting a very distinctly lamellated texture, the laminæ of which, are, however, not so broad as those of bismuth and antimony. When we place it beside these two metals, we perceive the marked difference of its colour. Its density is such, that it loses in water about a seventh part of its weight, and weighs 7,190. It is sufficiently hard and elastic not to break so easily as any of the metals which have hitherto been treated of; accordingly, I have placed it in the third division of the metals possessing considerable ductility.

8. In fact, zinc is not brittle, like the preceding metallic substances. It requires a violent and sudden stroke to break the flat plates, or blocks of it, such as we meet with in commerce; and when it is in thick ingots, we are obliged, in order to vend it in fragments, to cut it with iron wedges, struck into it by means of heavy hammers. When it is hammered upon a steel-anvil, it becomes flattened instead of breaking: it is reduced into thick plates, which do not crack till after they have been very considerably flattened

tened. It may be extended, without breaking, into pretty thin plates, by passing it through the flatting-mill with an even and gradual pressure: these plates are flexible and elastic, but very far from exhibiting the softness and pliability of those of the soft metals.

9. Its tenacity, however, is but weak. Files act upon it with difficulty; it adheres to the interstices between their teeth, so as to clog them, to use the expression of the artificers. Accordingly, when we wish to procure it in minute fragments, destined for a great number of experiments, we are obliged to divide it by pounding, or by pouring it fused into water. Macquer observes, that it becomes brittle, and that we may pulverize it in a mortar, if we heat it to a degree short of that which fuses it. The best process which we can employ for pulverizing zinc, consists in fusing it, and pounding it in a heated stone mortar, so as to divide its molecules, to prevent their re-uniting and striking together whilst they are cooling, and to keep them separate at the moment when they become fixed. When it has cooled, it is passed through a hair-sieve, which by retaining the grosser particles, affords a powder of zinc, which is finer than most of the filings of metals.

10. The conducting power of zinc, with respect to caloric, has not been determined: all that is known is, that it is heated very quickly, and that it dilates readily, and to a great degree. It fuses as soon as it becomes red-hot,

in which respect it is ranked amongst the metals of a middling fusibility. Citizen Guyton estimates this property at 296 degrees of Reaumur's scale. If we continue to heat it, after its fusion, in close vessels, it rises into vapour, and sublimes, attaching itself in a brilliant, metallic, and lamellated form to the upper part of the vessels. If we let it cool quietly after it has been fused, it crystallizes into needles, which are generally very fine, the form of which has not been determined. The unfortunate mineralogist, Mongez, the elder, who was lost with La Peyrouse in his voyage round the world, is the first who caused this metal to crystallize; he fused it for this purpose in a pretty deep earthen vessel, perforated with several holes at the bottom, which he stopped up with earth of bones. When the zinc which he fused in this vessel was fixed at its surface, he opened the holes, introduced a red-hot iron, which he stirred in the mass of the metal, and thereby caused the portion, which was still liquid, to run out, after which he found crystals, shaped like needles, in the cavities which it had left.

11. Zinc is a conductor of electricity like all the metals, and nothing particular has hitherto been discovered in it with respect to this property; however, the powerful manner in which it affects the sensibility of the human body in Galvanic experiments, seems to give it herein a sort of prerogative or pre-eminence over other metallic substances. If we place a plate of  
zinc

zinc under the tongue, and cover the upper surface of this organ with another metal, and especially a piece of gold or silver, and then incline the extremity of this last so as to approach it to the plate of zinc; at the moment when the two metals come into contact with each other, the person who performs the experiment, feels a very perceptible pricking sensation, heat, irritation, and a sort of acerb taste in the tongue, almost always accompanied with a momentous glare, or a luminous circle, which suddenly appears before his eyes. No metal produces this singular effect with such force as zinc is observed to do.

12. We also find in this metal a slight odour and a peculiar taste with which the fingers become impregnated when they are kept for some time applied to this metal or rubbed upon it. Though these two properties are easily and unequivocally recognized as being metallic, and though, in this respect, they resemble those which are found in several other metals, it cannot however be doubted that they are not the same in zinc as in other metallic substances. Zinc also adheres strongly to the skin, and tinges it black. This is a metal which is surrounded with one of the most perceptible metallic atmospheres, and which applies itself the most quickly, and by the slightest contact to all the substances upon which it is rubbed. Thus, for example, we need only draw a plate of zinc over a plate of iron, silver, or lead, in order to  
give

give these metals the power of acting in galvanic experiments, as if they were other metals than what they really are, namely of producing, by communication with plates of the same kind, convulsions in the muscles of frogs ; which shows that their surface is covered with a layer of zinc, which performs the function of a different metal.

### C. *Natural History.*

13. SEVERAL mineralogists have thought that zinc is one of the most abundant metals in nature, and that it constantly accompanies the ores of iron ; but though the ores of zinc are in considerable plenty in various countries, yet their abundance is very far from being comparable to that of the ores of iron ; and besides, it is at present well ascertained that the metallic substance that is so often mixed with the iron is only oxide of manganese, which the same mineralogists have long mistaken for zinc.

14. Citizen Haüy, the last, the most learned, and most accurate author on Mineralogy, enumerates only three species of ores of zinc, namely, its native oxide, its sulphuret, and its sulphate. Valmont-Bomare says, he has seen in the ores of Goslar, and in those of the Duchy of Limbourg, which are very fertile in this metal, native zinc which is found in small pliable filaments, of a greyish colour, and easily inflammable.

mable. This observation has not been confirmed by other naturalists. Some authors admit native carbonate of zinc, and some think there are reasons to doubt its existence, but we shall soon see that this salt does really exist in nature. Frequently the ores of zinc are mixed with ores of lead, iron, and manganese; but we have here only to enumerate those in which zinc is the most abundant metal.

15. The oxide of zinc, or oxidated zinc, forms the calamine of the ancient mineralogists. This ore of secondary formation deposited in layers, either in a regular form, or in incrustations and stalactites in the interior of the earth, has generally presented only very small crystals, semi-transparent, whitish, and of an unctuous aspect, easy to be recognized; their most common form is that of a rectangular lamina, the edges of which are replaced by facets or segments of cuneiform octahedrons, or an elongated quadrangular pyramid projecting out of its gangue. This form is also found in the sulphate of barites. The crystals of native oxide of zinc presented to Citizen Haüy the property of becoming electric by the action of heat without friction, like the tourmaline. The heat of a lighted taper applied to them for two or three seconds is sufficient to exhibit this property. I shall here observe, with the celebrated mineralogist to whom we owe this discovery, that five minerals are already known which possess this property; three stones, the tourmaline, the

topaz, and the zeolite; one salt, the native magnesian-calcareous borate, and the fossil crystallized oxide of zinc.

The oxide of zinc is frequently in irregular masses, foliated, cavernous, granulated, hard or friable. It is found of different colours, and especially grey and yellowish, even amongst the transparent specimens. It exists in abundance near Limberg, Namur, Friburg, and in the counties of Nottingham, and Somerset. Bergman has also found it to contain silica, alumina, and oxide of iron in different proportions. The zinc varies in it from 0,04 to 0,30.

According to Citizen Haüy, the modern mineralogists, in distinguishing calamines containing carbonic acid, or native carbonates of zinc, have been guilty of errors, and even of contradictions, for some arrange them improperly amongst the oxides; others, on the contrary, class amongst them oxides in which an exact analysis has not found this acid. Such is the native oxide of zinc of Brisgau, examined by Pelletier, which Deborn ranges in the species of carbonate of zinc. By treating fragments of this same oxide, which had been procured from different places, with nitric acid, Citizen Haüy has observed no effervescence; he has observed that the earthy powders which frequently envelop them, dissolve in it with an extrication of bubbles, and he is thence led to believe, that the effervescence is owing to the carbonate

carbonate of lime mixed amongst the native oxide of zinc. I shall shortly prove that there really exists a native carbonate of zinc.

16. The sulphuret of zinc, or sulphurated zinc, has been termed *Blende*, or False Galena, by the mineralogists. It is frequently disposed in scales, sometimes crystallized in tetrahedrons, in octahedrons, in dodecahedrons. Its colour is sometimes yellow, like honey, frequently metallic, and analogous to that of lead, or brown, deep violet, and even black, often reddish. It is frequently found mixed with the sulphuret of lead or galena, with which it seems to form a kind of metallic brechia. Before the nature of the metal contained in this ore was known, it was termed *Sterile Nigrum*, because, with the appearance of an ore of lead, none could be extracted from it by the metallurgical processes; the zinc, which was not at that time suspected to exist in it, exhaling in the form of vapour. Many of the sulphurets of zinc are more or less phosphorescent when rubbed in the dark; some are even so strongly so, that, by merely rubbing them with a tooth-pick, we cause torrents of light to be emitted; they exhale an hidro-sulphureous smell, and yield sulphurated hidrogen gas when treated with the acids. Their nature is not well known; it is not ascertained whether the zinc exists in them in the metallic state, or in that of oxide; whether it be united with the sulphur alone, or whether there are one or more other bodies which



serve as intermediums. Some chemists have supposed iron, and others lime, to exist in them. The following are the principal varieties that have been distinguished, of the sulphuret of zinc.

*a.* Dodecahedral sulphuret of zinc, with planes in the form of rhombuses: a form which is obtained from the masses of sulphuret of zinc by neat sections. It has always additional facets.

*b.* Sulphuret of zinc, with twelve trapezoids and twelve triangles.

*c.* Sulphuret of zinc in a regular octahedron.

*d.* Sulphuret of zinc in a regular tetrahedron.

*e.* Sulphuret of zinc; numerous varieties of colour.

*f.* Sulphuret of zinc phosphorescent and non-phosphorescent.

*g.* Sulphuret of zinc in decomposition, laminæ separated, its lustre destroyed, passing into the state of oxide.

17. The sulphate of zinc is found in a native state, and is very easy to be distinguished by its whiteness and transparency, its acrid and strong taste, its solubility in water, its aqueous fusion. It is rarely found in the earth in rhomboidal crystals, but most frequently in stalactites or in fine needles, and silky filaments, resembling those of the amianthus; in the latter state it has often been confounded with the plume-alum. It is found in Italy; and in the mines of the Hartz.

18. The

18. The native carbonate of zinc, which is usually confounded with the oxide of zinc or calamine, is transparent, white or yellowish like that substance; it is frequently found in the same places. Citizen Vauquelin has examined a very pure specimen of it in the mineralogical collection of Citizen Macquart. This salt, which is insipid and insoluble in water, dissolves entirely, and with a lively effervescence in the nitric and muriatic acids.

#### *D. Assay and Metallurgy.*

19. THE docimastic assay of the ores of zinc, that at least which was considered as applicable to the metallurgic knowledge of its nature was very simple and very inaccurate. It consisted in pulverizing the oxides of this metal, or its calamines, mixing them with charcoal, and heating this mixture in a crucible which was covered with a plate of copper. The oxide was reduced into zinc, which was volatilized by the heat and united with the copper, and converted it into brass or yellow copper. The richness of the ore was judged of, according to the force or intensity of the white colour; but it is evident, that this rude assay could only serve, on the one hand to ascertain the existence of an ore of zinc, and on the other to prove that this ore was capable of converting copper into brass. The sulphurets of zinc were roasted in order to separate the sulphur from them, and  
the

the residue of this roasting was treated in the same manner as the calamines.

20. Citizen Monnet was the first who proposed to make the assay of these ores by means of the nitric acid, the action of which, he thought, ought to dissolve the metal and separate the sulphur from it, and afterwards to reduce the oxide of zinc separated from the acid by distillation. Bergman, however, has greatly extended and improved the processes of this analysis by the humid way. He employed sulphuric acid in order to analyze the oxides of zinc; he precipitated these oxides by means of the carbonate of soda; and he found that 193 parts of this precipitate represented 100 parts of metal. As he employed zinc in order to separate the solution of iron, which is often mixed with these ores, he subtracted from the weight of the precipitate the quantity of metal employed in this operation. As the greater part of the native oxides of zinc contain more substances than iron and zinc, and especially alumine, silice, carbonate of lime, with the oxides of iron and lead; the following is the method which he has described in order to proceed with accuracy in the analysis of these complicated ores. The pulverized oxides are treated three successive times with two parts of nitric acid; heat is afterwards applied till the whole is reduced to dryness: by this means the iron is highly oxidated, and becomes insoluble in the acids. He dissolves the soluble part by means of a  
fourth

fourth dose of nitric acid: the oxide of iron, the flux and the alumine remain together without being taken up. The acid holds in solution lime and the oxides of zinc and lead. The last oxide is precipitated by the muriatic acid; the lime is separated by the sulphuric; the oxide of zinc is precipitated by the prussiate of pot-ash: and the fifth part of the weight of the last precipitate indicates the proportion of the zinc. He has also employed sulphuric acid heated to dryness, lixiviated the residue with water, and precipitated this lixivium by means of ammonia, in order to separate the oxide of iron and the alumine from the oxide of zinc, which is very soluble in this alkali.

21. As to the sulphurets of zinc, Bergman, who has also examined them much in detail, describes, in his Dissertation on the ores of this metal, the method which he has followed in order to effect their analysis. He first separated from them, by distillation, the water, the arsenic, and a portion of sulphur; he afterwards treated them with different acids, according to their degrees of solubility in these substances, and precipitated them by means of the different reagents known in the art, of which I have already had frequent occasion to speak. He found such great differences between the various sulphurets of zinc from different countries, that the ores seem to possess no general or identical properties and composition. There is, however, reason to believe, that these operations

are as yet far from having been brought to perfection, and that it is necessary that able chemists should still employ themselves upon them. Important discoveries still remain to be made, as well upon the sulphurets of native zinc, as upon the different ores of this metal. Thus, by reducing a pulverized calamine in close vessels, Citizen Vauquelin obtained hydrogen gas holding zinc in solution, and proved, as I had long suspected, especially with regard to arsenic, tin, and iron, that various metals are soluble in that inflammable gas, like carbon, phosphorus and sulphur.

22. The ores of zinc are rarely worked by themselves, or with the sole intention of extracting this metal. It will be remembered that I remarked above, that their particular treatment, and the extraction of zinc was not spoken of till towards the commencement of the eighteenth century. It is most frequently by fusion of the ores of lead mixed with sulphuret of zinc, that the latter metal is obtained in two forms; in that of oxide of zinc, proceeding from the zinc which has been sublimed and burned during its sublimation, which attaches itself to the chimnies of the furnaces; where it forms incrustations of a grey colour, granulated, as it were earthy, which are known in metallurgy and in commerce by the names of *Tutty*, or *Cadmia* of the furnaces;—and in that of metal which is obtained by moistening with cold water the anterior part of the furnace, which is thinner

thinner at this place, and which is termed *chemise* in metallurgical language. The zinc, being reduced to vapour by the action of the fire, condenses itself at this place, and falls back in the form of small grains into the pulverized charcoal, which is strewed upon a stone placed at the bottom of the chemise, and termed, on account of its use, the zinc-plate (*l'assiette du zinc*). The charcoal preserves the metal from being oxidated; it is afterwards fused a second time in a crucible; it is then cast into ingots rounded on one of their sides, or into plates several centimetres in thickness, and several decimetres in length or breadth. This process is chiefly practised at Rammelsberg, from whence the commerce of France is particularly supplied with this metal.

23. The art of extracting zinc in the large way is capable of receiving a great degree of perfection, and will gain much by being more studied than has hitherto been done. We are utterly ignorant of the processes employed by the nations of the East, and particularly the Chinese, who make much greater use of this metal in their alloys, than most of the European nations. A great number of the Chinese wares are wrapped or inclosed in leaves or vessels of a soft alloy, possessing a greater or less degree of resistance, grey, a little oxidated at its outer surface, frequently carved or moulded in different ways, and in which zinc is one of the most abundant principles. It is brought to us  
from

from this nation, amongst whom industry has so highly flourished during a great number of ages, under the name of *Tutenague*,—a much purer species of zinc than that of Rammelsberg, which always contains lead. In 1775, Mr. Engestrom made the analysis of a brittle calamine of China, which Mr. Kirwan terms *Tutenague*, in his mineralogy, and which contains from 0,60 to 0,90 of zinc. It is from a similar ore that the Chinese extract their zinc, though we are not acquainted with the process which they employ for that purpose. Some mineralogists assert, that zinc is extracted in England, from its native oxide by distillation or sublimation; though neither the means nor the apparatus used in this important operation are hitherto known.

#### E. *Oxidability of Zinc by the Air.*

24. ZINC suffers only a very slow, and a very slight alteration by the action of cold air; its lustre is a little tarnished, and in the course of time it becomes covered with an extremely thin layer of grey oxide; that also which is seen upon the blocks and the ingots of commerce is not produced except when this metal, being poured out into open vessels, has been very hot, and exposed for some time to the atmospherical air, whence it has taken a small quantity of oxygen which has oxidated its surface. When zinc, fused in close vessels, is exposed

posed to hot air, at the moment when it begins to become fixed, it assumes blue, yellow, and brilliant rosy tinges, which resemble those of the rainbow. This is a commencement of oxidation.

25. When zinc is fused in contact with the air, the temperature not being raised higher than is requisite to melt it, or at least, not much higher, its surface acquires rainbow colours, becomes wrinkled, loses its brilliancy, and soon assumes a dirty grey colour. When we take away this portion which forms a pellicle, a second is formed similar to the first, which being separated in its turn, is replaced by a third; and the whole zinc is susceptible of being changed in this manner to the last layer. This grey oxide is formed much more quickly, when we agitate the fused metal considerably and cause it to touch the air in many of its points. By heating the grey clots which are thus obtained in contact with the air, they gradually divide themselves, and become an uniform grey powder, which at last assumes a dirty yellowish colour. The oxidation of the zinc cannot then be carried farther by this process. The yellow oxide that has been formed in this manner weighs about seventeen parts more than the zinc in the hundred parts of the latter. It is easily reduced into zinc by the action of ignited charcoal; when a very strong heat is applied, it is fused into a yellow glass.

26. When



26. When zinc is strongly heated in a crucible, so as to render it of a bright red; and when after having opened this vessel, we agitate the zinc thus ignited to redness and almost raised to the point of volatilization, it suddenly kindles and emits a flame of a white colour with a slight greenish tinge, which is extremely brilliant, and by strongly illuminating all the surrounding objects, presents a very beautiful spectacle. Amongst all the metals this burns with the most sensible flame, and at the lowest temperature. As this rapid combustion, this deflagration, which has been compared with justice to that of phosphorus, on account of its lustre, its vivacity, its colour, as well as the strong heat which accompanies it, takes place at the moment when the zinc is converted into vapour, and partly in the vapour itself, the oxide of zinc which is suddenly formed, and which produces in the air a white, odorous and acrid smoke, the sensation of which particularly affects the fauces, is condensed in the atmosphere in flakes, and in a kind of filaments of a beautiful white colour, very light, and of a very delicate texture, much resembling those light filaments produced by an insect which is wafted along with the wind in the spring and autumn. This oxide formed in the air has been termed *flowers of zinc*, *pompholix*, *nihil album*, *philosophical wool or cotton*.

27, The

27. The sublimed oxide of zinc, *oxidum zinci sublimatum*, is entirely saturated with oxygen; it contains much more of it than the grey and yellow oxide of which I have spoken No. 24, since it is the product of a much stronger combustion, and it stands in the same relation to this first oxide as the phosphoric to the phosphoreous acid. Some modern chemists think it contains more than half the weight of the zinc in oxygen, and Citizen Guyton makes the proportion of this principle amount to 0,61. It is not volatile by itself. It emits for some time after it has been prepared, a phosphoric light. It is irreducible, and the action of the strongest fire does not cause it to give out any of its oxygen, but fuses it into a glass of a very pure yellow colour. The oxygen exists in it in a state of great condensation and fixity. Even with the addition of carbon, it is not reduced but with difficulty, and a very high temperature; and this operation succeeds only in close vessels. It sublimes during its reduction. The hydrogen contained in the charcoal, and disengaged by the action of the fire during this reduction, carries away with it a portion of zinc which renders it ponderous, with the property of burning with a brilliant flame and a deposition of oxide. In general, this oxide of zinc retains the oxygen which is combined with it with much obstinacy, and no metal can take it away from it. It would be very useful to  
examine

examine it by all the means which the science in its present state affords; for it promises important discoveries.

*F. Union with the Combustible Substances.*

. 28. No combination is known between azote and zinc, nor between this metal and hydrogen; the latter substance dissolves metallic zinc and raises it in the form of gas under certain circumstances; but this gas reduces the oxide of zinc at a high temperature. Neither is there any known combination of carbon and zinc; though a small quantity of carbon is frequently extracted from this metal; but as the carbon which is separated from it is combined with iron, it is thought that this last metal has in some manner introduced it into the first. We shall soon return to this fact.

29. Phosphorus combines very well with zinc with the aid of heat. Margraff had only seen the union of its oxide with this combustible body, and obtained it in a sublimate of an orange-red colour. Pelletier, who has made many experiments upon this combination, has observed the same composition in red sublimate; but he has carefully distinguished from it the phosphuret of zinc, which he has made, either by heating zinc with phosphorus in a crucible, or by distilling these two substances  
in

in a retort, or by decomposing vitreous phosphoric acid by charcoal and adding zinc filings to this mixture. The process which he has found most successful consists in throwing phosphorus upon zinc heated to redness in a crucible. In this manner he has obtained a phosphuret of zinc of a metallic appearance, less white than the zinc, and even of a leaden grey colour, which extended itself a little under the hammer, diffused a phosphoric odour on the application of fire, and left a spongy residue. He observes, that by heating zinc and phosphorus in a retort, part of the metal is always oxidated, and that on this account we obtain a red sublimate which has already been mentioned; he ascribes this effect to the water, of which, according to him, it is very difficult completely to deprive it.

30. Zinc cannot be combined with sulphur in a direct manner: when those two combustible substances are heated together in a crucible, the sulphur separates without uniting with the zinc, which only becomes a little more infusible. Mr. Dehne has observed, that when these two substances are kept together in the state of fusion in a crucible, the zinc becomes oxidated, and then unites with the sulphur, assuming a brown or grey colour. Citizen Guyton has discovered, since the observation of Mr. Dehne, that we may easily combine together the oxide of zinc and sulphur by fusion,

fusion, and that the result of this process was a mineral, or a sort of grey ore, similar to the sulphuret of zinc of Huelgoët, from which prismatic needles of a brilliant yellow colour were sometimes raised and sublimed upon the lid of the crucible. Hence he concludes, that blende contains the zinc in the state of oxide, but that it differs from the artificial combination, being formed in the humid way, as appears from the water which it contains, whereas we are not yet able to form this combination artificially except in the dry way. Malouin has ascertained that the liquid alkaline sulphurets do not dissolve zinc.

31. Zinc combines with several metallic substances; it refuses to enter into alloys with cobalt, bismuth, and nickel; when these metals are fused together, they are afterwards found separated according to the order of their specific gravity. Nothing is yet known concerning the reciprocal action of tungsten, molybdena, chromium, titanium, uranium, and manganese, upon zinc. Its combinations with arsenic, antimony, and mercury, have been examined.

A. Malouin has found that metallic arsenic does not unite so well with zinc as its oxide or arsenious acid. However, by distilling a mixture of this acid, tallow and zinc, he obtained a blackish mass, resembling *blende*, but more tender. It appears, that when the arsenious acid

acid unites with it, it yields its oxygen to the zinc, and again passes into the metallic state. However, the experiments of Malouin on this combination ought to be resumed.

*B.* Zinc and antimony easily combine and alloy with each other by fusion; they form a hard alloy, with small facets, and brittle, which seems to resemble steel. The fulphuret of antimony, fused with this metal, remains separated from it.

*C.* Zinc unites with mercury even by trituration. According to Pott, this combination may be better made by uniting fused zinc with hot mercury; an amalgam is formed which easily becomes fluid by trituration. It crystallizes by slow refrigeration into square laminæ, with level edges. It crackles over the fire. Several chemists assure us, that when it is washed in hot water, the zinc separates from it in the state of oxide. Moreover, it is thought, that zinc separates antimony from mercury; and this accords with the difference of the degrees of adherence for this liquid metal which Citizen Guyton has pointed out; for antimony adheres to it only with a degree of force represented by 126, whilst that of zinc is expressed by the number 204.

*G. Action upon Water and the Oxides.*

32. ZINC has a great tendency to decompose water, in consequence of its great attraction for oxygen. Accordingly, this metal in the state of powder, left even in the cold in contact with water in the upper part of a bell glass full of mercury, produces an effervescence, forms a grey powder of oxide, and yields hydrogen gas. This action increases to such a degree, and becomes so violent in high temperatures, that the effervescence and ebullition produces dangerous detonations, as Lavoisier has remarked. We shall soon see that this decomposition takes place in many other experiments, and that on this account zinc is frequently employed by chemists for the purpose of obtaining the purest hydrogen gas which they are able to procure.

It is very remarkable that this oxidability of zinc by water is singularly augmented when we place it upon another metal whilst it is plunged in this liquid. Thus when two plates of zinc are placed in two glass vessels, the bottom of which is covered with a sufficient quantity of water for the zinc to be immersed in it, and when the condition of this metal is varied in such a manner, that in one of the vessels it is alone in contact with the water, whilst in the other vessel it rests upon a plate or a piece of silver, the latter plate is covered, and  
as

as it were, enveloped with flakes of white oxide at the end of some hours ; whilst the plate of zinc that has been left alone, is either not oxidated, or exhibits only a slight appearance of oxidation.

33. This metal acts with much energy upon most of the metallic oxides, from which it takes away in a red heat the greater part of their oxygen. As it holds the second rank after manganese, in the order of the attractions for this principle, it may be employed to decompose almost all the oxides ; and as it is at the same time the metal which absorbs oxygen in the most solid state, it frequently inflames at the moment when it seizes upon this principle. Thus by rapidly heating, in a glass retort, a mixture of zinc in the state of fine filings, or powder, with red oxide of mercury, we see at the moment when these substances become ignited to redness, a flame or sparks which run through and fill the apparatus, and afterwards find the mercury reduced, and the zinc in the state of oxide lining the sides of the retort throughout.



*H. Action upon the Acids.*

34. THERE is no metal which exerts a more prompt action upon the acids, which decomposes them, or the water which accompanies them, with greater activity, and which is dissolved more abundantly in these bodies. The sulphuric acid, diluted with water, and poured upon zinc in filings or in fragments, appears to attack it with force; a lively effervescence is produced suddenly and in the cold, and the mixture becomes much heated. A large quantity of hydrogen gas is disengaged, which holds in solution a little carbon, but which however is one of the purest and lightest which the chemists are able to obtain. Accordingly, it is this gas which they employ for re-composing water in their exact experiments; and it is the same which, in the experiment which I made in 1790 with Citizens Sequin and Vauquelin, afforded us very pure water free from acid. The small quantity of carbon, dissolved in the hydrogen gas thus obtained, proceeds from the small portion of carburet of iron contained in the zinc, of which I shall immediately speak. It cannot be doubted that the water, decomposed by this metal, which has great avidity for oxygen, is here the source of the gas, since the concentrated sulphuric acid does not dissolve

solve zinc except with the assistance of heat, and since when decomposed itself, in the state of concentration, it affords sulphureous acid gas. The water, therefore, in this case, effects the oxidation of the metal, and the oxide becomes dissolved in proportion as it is formed in the sulphuric acid, which, in fact, is found perfectly entire after the solution. In proportion as this solution takes place, we see a small quantity of very black powder in a state of extreme division floating in the liquid, which has long been mistaken by chemists, and which is nothing else than carburet of iron or plumbago, existing originally in the zinc, from which it separates because insoluble. When the extrication of hydrogen gas has ceased, and the solution of the zinc is completed, the liquid has a singular smell, analogous to that of rancid fat; it is turbid and replete with a white powder, which gradually disappears, and suffers the solution to assume a perfect transparency when we add water which dissolves it. By evaporating it in a proper manner, and leaving it to cool, we obtain the crystallized sulphate of zinc.

35. The sulphate of zinc, sufficiently pure and prepared in this manner, is white and transparent. It crystallizes in tetrahedral prisms, terminated by pyramids with four faces; the faces of these prisms are smooth, and have some resemblance with those of sulphate of magnesia. This crystallization is not very difficult, and

when the salt is pure, it always succeeds well by the cooling of its solution a little condensed by the heat. This salt has a pretty strong acrid, styptic, and metallic taste. It is also prepared by dissolving the grey or white oxide of zinc in sulphuric acid, which, however, saturates itself with much greater difficulty than when the metal is gradually oxidated by means of water. When sulphate of zinc is heated in a retort, it melts, loses its water of crystallization, gives out a portion of its acid in the state of sulphureous acid and a little water; it dries and becomes in part decomposed; so that when we afterwards attempt to dissolve it again in water, a portion of oxide of zinc remains insoluble. Exposed to the air, the sulphate of zinc effloresces, and loses its water of crystallization: it is decomposed and precipitated in a white oxide by all the alkalis, and these precipitates, especially those that have been made by the carbonates, are capable of affording white pigments for painting. This precipitated oxide is soluble in the acids, and in an excess of the precipitating alkalis, especially of ammonia. The sulphate of zinc is also decomposed with the aid of heat, by nitre, which it decomposes at the same time: from this decomposition, when made in a retort, there results nitric acid, in part nitrous, and sulphate of pot-ash mixed with oxide of zinc. The alkaline sulphurets and the hidro-sulphurets  
also

also precipitate the sulphate of zinc in a deep orange or brown colour; sulphurated and hydrosulphurated oxide of zinc are then deposited.

36. There exists in commerce, under the names of *white copperas*, *white vitriol*, *Goslar vitriol*, a sulphate of zinc which is prepared in the large way at *Goslar*. It is in the form of white masses granulated like sugar, and often spotted with yellow. It is prepared by roasting the native sulphurated oxide of zinc or blende; treating this roasted ore, already changed into sulphate by the combustion of the sulphur with an addition of water; decanting the clear liquor, then evaporating it, and causing it to crystallize suddenly by refrigeration, and lastly, by fusing the salt to deprive it of a portion of its water of crystallization, and obtain it in irregular, solid, and granulated masses. This salt exhibits all the properties of the sulphate of zinc which has just been described; it differs from it only in being impure and containing sulphate of iron: accordingly, when we dissolve it and leave the solution exposed to the atmosphere, a red oxide of iron is separated from it, and the crystals which we obtain have frequently a rose-colour; which is a certain indication of the presence of the latter metal, which is, besides, proved to exist in it by the violet or black colour that the solution of this impure salt assumes, as soon as we add to it a small quantity of nut-gall. It is also thought that this salt of commerce contains a small proportion

portion of lead. In order to purify it, it is advisable to put pieces of zinc into its solution, which precipitate the foreign substances. It is then very pure, and may be used for the same purposes as the artificial sulphate of zinc, provided that the zinc employed in the preparation of this latter salt be perfectly free from iron, which will be the case when in preparing it, we take care to put more zinc into the sulphuric acid than it is able to dissolve.

37. The sulphureous acid quickly attacks zinc in powder or in filings; a great production of heat takes place; sulphurated hydrogen gas is disengaged; the liquor first becomes brown; sometimes it becomes turbid, and assumes the yellow colour of sulphur; towards the termination of the action it becomes clear. This solution has a pungent, astringent, and sulphureous taste. The sulphuric and muriatic acids disengage sulphureous gas from it with effervescence, and precipitate from it a yellowish white powder. The nitric acid first separates sulphureous gas from it, and afterwards a flaky, ductile, and adhesive precipitate. The precipitate is real sulphur. When exposed to the air, the sulphureous solution of zinc thickens like liquid honey, affords needles or fine tetrahedral prisms with quadrangular and very sharp-pointed pyramids, which become white in the air, and form a white powder insoluble in water. Heated before the blow-pipe, this salt swells, emits a lively and brilliant light like that of  
burning

burning zinc, and rises in the form of the branches of shrubs of a very agreeable appearance, or in tubercles surmounted by a multitude of other smaller tubercles: this is one of the most singular and most pleasing spectacles that are presented by the experiments made with the blow-pipe. It is partly soluble in alcohol: the part which has not been dissolved yields only sulphureous acid gas by the sulphuric acid, whilst the part that has been dissolved, at the same time that it yields the same gas by this acid, presents an abundant precipitate of sulphur. Distilled in a retort, the sulphite of zinc affords water, sulphureous acid, sulphuric acid, sublimed sulphur; there remains some oxide of zinc mixed with a small quantity of sulphate of this metal. The yellow powder, separated from this salt by the acids, burns with a blue flame upon ignited coals; it is dissolved into a brown sulphuret by the liquid alkalis. Thus this salt is a sulphurated sulphite of zinc: in its solution by the liquid sulphureous acid, the metal has decomposed the water, and a portion of the sulphureous acid itself, since sulphurated hydrogen gas is disengaged; the sulphur that is separated is not precipitated during the solution, but combines with the sulphite of zinc; this, however, is not saturated, since the alcohol, whilst it dissolves only the portion of sulphurated sulphite which it contains, separates from it sulphite of zinc.

38. As zinc is one of the metals which present, with the greatest energy, the very remarkable properties of a double combination with the sulphureous acid; and as these combinations have not yet been properly described, or even indicated by chemists, I shall here give a somewhat circumstantial account of a second species of salt or fulphite of zinc that is not sulphurated like the preceding. It is the result of numerous experiments which I have made in conjunction with Citizen Vauquelin, which I am about to offer, as it throws much light upon compounds hitherto unknown, which, it is nevertheless, very useful to the progress of chemistry to distinguish. I have already indicated their bases in the first article of this section.

When the white oxide of zinc is mixed with sulphureous acid highly concentrated, these two bodies combine without motion, with a production of heat, and a destruction of odour on the part of the acid. When the saturation is complete, white imbricated crystals are formed upon the surface of the liquor. This salt or pure *fulphite of zinc*, compared with the preceding, or the *sulphurated fulphite of zinc*, presents the following properties:

*a.* It has a less pungent, but more styptic taste than the latter.

*b.* It is less soluble in water, and crystallizes more easily.

*c.* The

c. The acids hitherto known, or with simple radicals decompose it with effervescence, but they do not separate from it any sulphur, as from the sulphurated sulphite.

d. It is insoluble in alcohol, whilst the preceding is entirely, and even abundantly soluble in it.

e. It forms white precipitates with the alkalis, whilst the sulphurated sulphite affords yellowish precipitates.

f. Exposed to the air, it is speedily converted into sulphate of zinc, whilst the sulphurated sulphite may be exposed to the air for a great length of time without undergoing any alteration.

g. The precipitate which the sulphite of zinc yields by the alkalis is completely soluble in the cold in sulphuric acid; that furnished by the sulphurated sulphite is only partially so, and leaves pure sulphur after the separation of the oxide of zinc by this acid.

h. All the properties of this sulphite of zinc are changed, and sulphurated sulphite is formed, when instead of dissolving pure oxide of zinc in sulphureous acid, we treat a mixture of sulphur and oxide of zinc with this acid in the heat. However, it is less sulphurated by this operation than that which is prepared with zinc and sulphureous acid, since in the latter case, the zinc, whilst it decomposes the sulphureous acid, and separates the sulphur from  
it



it, unites with it more intimately and more abundantly, on account of its great state of division.

39. The concentrated nitric acid is capable of inflaming zinc: in order to effect its solution, this acid must be taken in its weak state, and the zinc in rather coarse fragments. A considerable heat is produced; the effervescence which accompanies the solution, gives rise to a disengagement of a large quantity of nitrous gas, which reddens suddenly and strongly with the air when the operation is performed in open vessels; by this means a large quantity of nitrous gas may be collected. Thus the zinc rapidly decomposes the acid of the nitre, and takes oxygen from it. When this metal contains iron, this is separated at the surface of the solution in the form of a reddish oxide; when it is pure, it leaves only a small quantity of black powder of carburet of iron, like the sulphuric acid. The oxide of zinc, in proportion as it is formed, dissolves in the nitric acid, which even takes up much more of it than the sulphuric acid. This solution is frequently of a greenish yellow colour; it is very caustic, though made with an acid diluted with water. By evaporation and refrigeration, it affords crystals in tetrahedral compressed and striated prisms, terminated by pyramids with four faces. This salt melts upon the coals, and becomes fused with crackling, in the part which is desiccated. During

ing its detonation it emits a small reddish flame. When fused in a crucible, it quickly affords an extrication of red vapours; it assumes a deep colour and a gelatinous consistence. When cooled in this state, it retains its softness for some time. By continuing to heat it, it becomes dry, affords nitrous and oxygen gas, and leaves a yellowish oxide. Hellot had insisted upon the nitrous acid extracted from this salt, and the red colour which it assumes during its fusion. The nitrate of zinc attracts the humidity of the atmosphere, and loses its form. It is perfectly decomposed by the sulphuric acid; the alkalis precipitate from it a white oxide which they re-dissolve, and the alkaline carbonates produce, by precipitation, a very white carbonate of zinc. The nitrite of zinc is not known, though it is very probable that the nitrate, after being heated, and having assumed a red colour, is in this state.

40. The muriatic acid acts upon zinc with much rapidity; it dissolves it, producing a brisk effervescence and a disengagement of very pure hydrogen gas; it therefore, powerfully promotes the decomposition of water by this metal. In proportion as the oxidated zinc dissolves in the muriatic acid, a black powder of carburet of iron is separated. The muriatic solution of zinc is white and colourless; it affords no crystals, how far soever we may carry the evaporation; but it is reduced to a transparent and  
soft

soft mafs like a jelly. In diftillation, it yields a fmall quantity of very fuming acid, and a folid muriate of zinc fufible in a gentle heat, which was formerly termed *butter of zinc*. This muriate of zinc, when fublimed and congealed, is of a beautiful white colour, confifting of fmall prifms adhering the one upon the other. It is decompofable by the fulphuric acid, which difengages the muriatic acid from it in the form of vapour or gas. The alkalis precipitate it of a white colour; water does not precipitate it; it gradually attracts the moifture of the atmofphere, and foon forms a transparent jelly. It is alfo obtained by decompofing the fuper-oxygenated muriate of mercury by means of zinc.

41. When zinc is thrown in the ftate of powder into oxygenated muriatic acid gas, it inflames, and forms a white oxide as well as by the nitric acid. It is afterwards foluble in the muriatic acid, and forms the fame falt as is produced by the folution of zinc in this acid in its fimple ftate. The liquid oxygenated muriatic acid diffolves zinc without motion and without effervescence; for this metal becomes oxidated by quietly taking oxygen from it, and unites in proportion as it is oxidated with the difoxygenated muriatic acid. This folution does not differ from that of the metal, or its oxide in the fimple muriatic acid. We are not yet acquainted with the fuper-oxygenated muriate of zinc, which appears to be reproduced when we treat the muriate of zinc with the oxygenated muriatic acid.

42. The

42. The phosphoric acid diluted with water attacks zinc, with a disengagement of hydrogen gas, which is owing to the decomposition of the water; we soon see a white powder formed, which is deposited, and is the phosphate of zinc. We also obtain it in a white precipitate, owing to the effect of a necessary double attraction, when we pour into a solution of sulphate, of nitrate, or of muriate of zinc, that of the phosphates of pot-ash, of soda, or of ammonia. We are not yet acquainted with the characteristic properties of the phosphate of zinc. This metal, when heated strongly with the vitreous phosphoric acid, reduces a portion of it into phosphorus, with which it combines into phosphuret of zinc.

43. The combinations of the fluoric and boracic acids with zinc have not yet been examined. The first attacks it with effervescence and a disengagement of hydrogen gas. The second attacks it but very feebly by immediate contact, but it combines with its oxide when the nitric or muriatic solution of zinc is poured into the solutions of borate of pot-ash or of soda. The distinguishing properties of the borate of zinc have not been examined; we only know that it is insoluble in water.

44. Zinc thrown in the state of a fine powder into liquid carbonic acid, is oxidated and dissolved in sufficient abundance after remaining twenty four hours in this acid, for a pellicle

hicle of carbonate of zinc, of different colours, to be formed upon the surface of the solution exposed to the air, according to Bergman. This is undoubtedly the manner in which nature prepares the carbonate which is found in the secondary ores of this metal. Nothing can furnish a better proof, than this solution of zinc in water charged with carbonic acid, of the great tendency which this metal has to combine with oxygen, and the property which it possesses of easily decomposing water; for though no effervescence is here observed, it cannot be doubted that hydrogen gas is disengaged, as may be perceived from the smell of the solution.

45. The arsenic, tungstic, molybdic and chromic acids are susceptible of combining with the oxide of zinc, which, in the metallic state, decomposes them and robs them of their oxygen. Hitherto the arseniate, the tungstate, the molybdate, and the chromate of zinc have not been obtained unless by double attractions, by precipitating the nitrate of zinc by the combinations of these acids with alkalis. These salts are deposited in the form of powder, because they are insoluble in water; the three first are white, and the chromate of zinc is of an orange-red colour. These compounds are destroyed by the preceding acids in the insulated state.

I. *Action upon the Bases and the Salts.*

46. AMONGST the salifiable bases we are yet acquainted only with the action of the alkalis upon zinc. When we plunge it into solutions of pot-ash, or of soda, it becomes tarnished; its colour blackens; and even when these liquors are boiled a small quantity of hydrogen gas is disengaged; the alkalis then assume a dirty yellow colour, and a white oxide of zinc may be precipitated from them by means of the acids.

Ammonia, according to the experiments of Laffone, acts still more powerfully upon this metal in the cold; more hydrogen gas is extricated; the oxide thus formed is dissolved more abundantly in the liquor, and after some time, a large quantity of this white oxide is seen at the bottom of the volatile alkali. These alkaline solutions become turbid by exposure to the air, the oxygen and carbonic acid of which, acting at the same time, precipitate the oxide. This is another proof of the strong attraction of zinc for oxygen, and of the facility with which it effects the decomposition of water, assisted only in this case by the action of the alkalis.

47. Zinc decomposes the alkaline and earthy sulphates by the aid of heat. It seizes the oxygen of the sulphuric acid, and reduces it

to the state of sulphur which combines with the bases of the sulphates. These sulphurets, when once formed, combine, though not without difficulty, with the oxide of zinc; and when this fused mass is lixiviated, the water dissolves the sulphurets, which hold only a very small quantity of oxide of zinc in solution. The greater part of the oxide remains pure and insulated after this action of the water. Pott has observed, that zinc decomposes alum by ebullition: in this case a triple sulphate of zinc and alumine is formed.

48. The nitrates burn zinc briskly with the aid of a red heat; their acid is decomposed; the oxygen seizes the metal with which it unites in a more solid state and more intimately than was the case in the nitric combination; hence the activity and the lustre of the detonation and flame which accompany this rapid combustion. The azote is disengaged in the form of gas, and the result of this operation is an oxide of zinc at the *maximum* of oxidation, combined in part with the base of the nitrate which has been employed. Most commonly the nitrate of pot-ash is used for this combustion; three parts of it, well dried are mixed with one part of zinc in fine filings, or even in powder passed through the sieve; this mixture is thrown into a crucible heated to redness; the radiance of the inflammation which immediately takes place is such, that it throws  
out

out to a great distance from the vessel portions of burning matter, with flashes, and a very brilliant light; it is therefore necessary to operate with caution. The oxide of zinc, which is the product of the operation, is found united with the pot-ash; and when we lixiviate this residue, the water dissolves a portion of it with the alkali; so that we may ascertain its presence by pouring an acid into this lixivium. Hellot asserts that this liquor was considered and prescribed by one Respour, a skilful alchemist, as a species of alcahest, or universal solvent of metals. The beauty of the flame of the spectacle afforded by this rapid combustion of zinc by the nitrate of pot ash, has rendered it one of the substances employed by artificers in the construction of fire-balls which fly into the air, and throw out those white flames, those brilliant stars, whose beautiful light illuminates so large a space in the firmament.

49. Though the action of zinc upon the muriates is more feeble than its action upon the preceding salts, it is far from being inconsiderable. Pott has described some experiments which seem to prove that this metal is capable of decomposing the muriate of soda. Macquer observed that when triturated with the ammoniacal muriate, it disengaged the ammonia from it, even in the cold. Bucquet has observed, that by distilling this salt with zinc,

N n 2

ammoniacal



ammoniacal gas and hidrogen gas were obtained. The latter product can only be owing to the decomposition of the water contained in the salt, by the zinc, which affects it before it combines with the muriatic acid. The residue of this operation is muriate of zinc, which may be sublimed by a stronger heat. According to Hellot, the oxide of zinc produces the same separation of the principles of the muriate of ammonia.

50. The phosphates and the borates melt with zinc, and combine by fusion with its oxide, which gives to their glass a greenish yellow tinge. No decomposition of these salts is effected by the metal. Whatever attraction it has for oxygen, it cannot act, no more than charcoal can, upon the phosphoric acid combined with the earthy and alkaline bases, which, as we have seen in the preceding section, is powerfully fixed by these bases.

51. Zinc decomposes most of the salts and metallic solutions by its strong attraction for oxygen; it precipitates from them the metals in the metallic form by completely unburning them, or in that of oxides less oxidated than they were before. It is very useful in the analyses of ores on account of this property. Its oxide has also more attraction for the acids than most of the others.

*K. Uses.*

## K. Uses.

52. ZINC is applied to uses no less numerous than important in a great number of the arts. It forms a part of many considerably hard and white alloys. It is particularly employed in the fabrication of tombacs and brasses, of which we shall speak elsewhere. The eastern nations, and especially the Chinese make use of it, as has already been observed, much more frequently than the Europeans; undoubtedly, because they possess it in greater abundance than we do, and perhaps, because they are better acquainted with its useful properties. It has been proposed for lining copper: concerning this application we shall have occasion to speak in the history of the latter metal. Malouin, in his Memoirs inserted amongst those of the Academy for 1743 and 1744, has compared zinc with tin with relation to its economical properties, and has frequently given it the preference.

53. Zinc and its chemical preparations have already been applied to medicinal purposes, Its property of conducting so great a degree of animal electricity, may hereafter render it much more valuable to the healing art. Formerly, the sulphate of zinc was employed as an emetic, under the name of *gilla vitrolis*. The oxide of zinc prepared in the pharmaceutical laboratories, is prescribed as an antispasmodic,  
in

in doses from half a decigramme, one grain, to that of several decigrammes at most. It has been much extolled in the convulsive diseases of children, and was at first administered as an arcanum, under the name of fixed luna, by one Ludemann, in Holland. Gaubius, who examined this remedy, found it to be nothing more than oxide of zinc, which was then termed *flowers of zinc*. This oxide, and especially tutty and sulphate of zinc are employed as very good external remedies in diseases of the eyes.



END OF THE FIFTH VOLUME.

W. FLINT, Printer,  
Old Bailey.

